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CONWAY MACMILLAN, *State Botanist*

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I. CONTRIBUTIONS TO A KNOWLEDGE OF THE LICHENS OF MINNESOTA—III. THE ROCK LICHENS OF TAYLORS FALLS.

BRUCE FINK.

THE COMPOSITION AND ORIGIN OF THE FLORA.

The lichens listed in this paper were collected during two regular annual excursions of the Summer School of the University of Minnesota. The date of collection of all numbers up to 92 is August 15, 1896, and the plants were collected by Professor Conway MacMillan and the writer, on the Algonkian igneous rocks of the Interstate Park, or on earth or branches in the crevices of the rocks. On the 14th of August, 1897, I accompanied another excursion to examine the lichens growing on the Cambrian sandstone exposures near the park. Numbers 93 to 119 were collected by me during this second trip, and more species were noted on the sandstone, which had been collected the year before on the igneous rocks. In all, 24 lichens were found growing on both sandstone and igneous rocks, 22 on the igneous rocks only, 20 on the sandstone only, 10 on earth in the crevices of the igneous rocks and 2 on roots or branches in the crevices. The last lichen of the list was found on old boards and is recorded here because rare or difficult to detect and new to the State.

It was my intention when I went to the park to publish whatever might be found of interest with the last number of this series of papers. But after observing the field it became apparent that the locality is one of great interest both as to origin and present composition of its lichen flora and that these characteristic floral features could be presented best in a separate paper. A little observation showed that the tree lichens do not differ to any noticeable extent from those about Minneapolis, and I consequently confined my collecting to the igneous rocks and sandstone. There are rocks near the park containing lime, but they did not seem to support any lichens of special interest.

The collecting was all done on the Minnesota side of the river for the reason that the erosion of the valley has been such as to leave better exposures of rock here than on the Wisconsin side. I had collected from excellent exposures of igneous rocks in New England and have since visited similar ones in various parts of northern Minnesota; but I have never seen any other equally limited area of rock exposure that aroused so much interest, because of richness of lichen flora and evidence of migrations and struggle, as did this little area, set aside for an interstate park. During the trip of 1897 I noticed that the constant tramp of feet had begun to kill out the lichens in many places so that the impression of richness is beginning to fade, and the botanist must soon seek some place near by, if such exists, where he may study this rich flora in its natural beauty.

Professor E. E. Edwards, of Lancaster, Wisconsin, writes thus of the lichens found in the park: "The rocks of the Dalles owe their beauty and variegated tints not alone to the metal oxides, or to the feldspar or hornblende chiefly composing them, but to the growth of minute lichens upon their surfaces, and these vary in color according to the dryness or moisture of the atmosphere. We have, therefore, in these, through sunshine and shadow and the varying seasons, an endless and almost kaleidoscopic play of colors that makes them alike the delight and despair of the artist." The little area, being one of great natural beauty and set apart for an interstate park, will always attract thousands of visitors annually and I hope to present in this paper thoughts which will enable the botanist who has a fair knowledge of lichen species and their distribution to see in this wonderful lichen population something of far greater interest than mere beauty.

Some comparisons between the locality now under consideration and others will best show its richness in rock lichens. The area examined covers only a few acres of surface and gave 66 lichens growing on rocks as a result of two days' collecting. The whole region about Minneapolis when more thoroughly worked only furnished 30 saxicolous lichens, and the whole of Fayette county, Iowa, only 50. The latter region is surely better than the average for rock lichens, and I have studied it for six years. Probably however, the fact that I have not looked so closely in the last two localities for lichens not strictly characteristic of rocks, but still growing on them occasionally, about offsets the limited time spent in examining the area forming the basis of the thoughts here presented, so that the numbers given above, save for difference in areas covered in the three instances, may still be taken to represent, approximately, relative richness in rock lichens. But again, the Taylors Falls area, with one possible exception, gave me more such lichens collected in the two days than are recorded in any State list hitherto published.

The igneous rocks at Taylors Falls are essentially like those which outcrop occasionally between this place and Lake Superior, and the fact that Taylors Falls is practically the southern limit of outcrop of these rocks furnished the first suggestion of the interest involved in an analysis of their lichen-flora. Of the 79 species and varieties collected, only 8 are plants not yet found further south in Minnesota or Iowa. These 8 I have also found along Lake Superior, and they are species not commonly occurring further south except at high elevations. These are *Biatora rufonigra* Tuck., *Lecidea albocærulescens* Schær., three forms of *Buellia petræa* (Flot., Koerb.) Tuck., *Umbilicaria dillenii* Tuck., *Nephroma helveticum* Ach. and *Ephebe solida* Born., all forms found on the igneous rocks and none of them on the sandstone. Subtracting the 8 species and varieties leaves 58 rock lichens, nearly all of which occur in other portions of the southern half of Minnesota, but not all on rocks. Those not known to flourish on rocks in other parts of the State grow on them here under unusually favorable conditions to be explained below.

What has already been stated, especially the last paragraph above, merely suggests the problems of interest which I shall attempt to discuss and which involve a knowledge of geological conditions present and past, as well as acquaintance with lichen-species and their distribution in general. For the geological data concerning this area, I have relied largely on the researches of Dr. Charles P. Berkey, who has recently studied the region including Taylors Falls in detail, and who is therefore especially able to give the information needed for my purpose. The questions which I shall consider below are those which thrust themselves upon me as I observed and studied this extremely interesting lichen-flora; and though the area is a small one, the questions involved are, it seems to me, none the less worthy of consideration when we notice that it is one of a series of similar areas where certain floral elements have become isolated and gradually killed out by others.

The 8 species commonly found farther north have evidently migrated southward, and there are at least two views as to time and method or cause of migration worthy of consideration. First, the northern species might perhaps have migrated from Lake Superior along the exposures of igneous rocks extending from the lake to four or five miles below Taylors Falls in quite recent times, long after the retreat of the last glacier. Second, they seem undoubtedly to be the remnant of a flora driven south, doubtless from some region far north of Lake Superior, by the advancing glaciers and left stranded on favorable substrata at Taylors Falls as the southern extremity of a flora migrating south before the glacier or more probably migrating north on the return of post-glacial climate in the north temperate zone.

The outcrops of the igneous rocks between Lake Superior and Taylors Falls are not frequent enough to make either theory seem very plausible; but the second is reasonable since, under the influence of slow decrease in temperature to the southward, migration would naturally follow increasingly favorable climatic conditions in that direction even if the outcrops were not more frequent than now. However, it seems probable that at the time of the first glacial advance the outcrops were much more numerous than now. Also, the rock lichens, now found on the igneous rocks only, doubtless found a foothold on the sandstones on the line of retreat under the more favorable climatic conditions of glacial times. The numerous boulders of the same igneous rocks; scattered over the ground by the glaciers could help in the advance southward of some of the species since glacial times, but hardly of those seldom or never found on boulders, as the *Umbilicaria* listed. On the whole, it seems doubtful whether a single one of the 8 northern species has migrated southward in post-glacial times under increasingly unfavorable conditions as to climate and substrata.

As the remnant of a lichen-flora driven south by glaciers, these plants must either have been stranded during a late glacial advance, as during a slight advance during, or more probably after, the Wisconsin stage; or more probably have been driven further south than their present position by each of the earlier stages, or ages as the case may be, and retreated with each return of interglacial conditions. The 8 northern species at Taylors Falls are thus either a few of a former flora which has doubtless partly died out and partly migrated northward, or possibly a few species which migrated to the locality from the mountains to the east and west during a late glacial stage, as stated above, or even after the final retreat of the ice. Igneous rocks are not supposed to have been exposed over the region covered by the glaciers south of the area now under consideration at the time of the first glacial advance, but sandstone no doubt outcropped frequently and probably further south than the glaciers extended. For a long period after each glacial retreat the surface was no doubt thickly strewn with rocks left by the melting ice, and these rocks would furnish abundant substrata for a retreat of the saxicolous lichens to the north. These same boulders, now largely covered, would partly remain at the surface during interglacial conditions and furnish sufficient foothold for the organisms to remigrate during a subsequent advance of the ice, thus taking the place of the sandstone where it was covered by previous drift deposits. Thus several migrations, alternately southward and northward, probably followed in succession, and we are studying the last stage in the last northward retreat in this not yet completed series. Of course, it is apparent that the *Umbilicaria* and many other lichens not now found at Taylors Falls might have flourished on the sandstone and later on the boulders at a time when the climate was more favorable for northern species than now, at and south of the area under consideration, both as to temperature and moisture, and that they could have migrated readily enough with the advances and retreats of glacial conditions. What species of the rock lichens were able to endure these cycles of migration and what were killed out is not easy to conjecture. However, it seems certain that the region was left barren of such life and repopulated several times, and it is extremely probable that enough species survived the migrations, or possibly in part flowed in from the east or west as stated above, to give an arctic or subarctic flora at Taylors Falls for a time after the close of the ice age.

Since the time when this last northern lichen-flora became established in the region about Taylors Falls, there has been a gradual change toward a lichen-flora characteristic of the northern United States at the present time. No doubt the 8 northern species now found on the igneous rocks are being rapidly replaced by the more numerous species, which are better adapted to present climatic conditions. With the exception of the *Nephroma*, the 8 species persisting, all lichens confined wholly to rocky substrata, or essentially so, and being therefore favorably situated as to substrata, have persisted longest against unfavorable climatic conditions and the onslaughts of the species which are to-day surely replacing them. *Nephroma*, which is arboricolous as well as rupicolous, furnished only a few small, sterile specimens clinging to mossy rocks. *Ephebe* was seen in one spot only, and, so far as I could ascertain, *Umbilicaria* persists only in a few cool, damp or shaded spots. The three species named above, not closely attached to the rocks, would naturally succumb to unfavorable conditions sooner than those named below, and all of the three former are sterile and apparently just on the verge of extermination in the locality. The other three species all grow closer to the rocks and are all abundantly fertile. *Biatora* seems to be rare and is not strictly crustaceous as are the other two. *Buellia* is the most common of the 8 northern species and is one of two that would be expected to persist longest because of its strictly crustaceous habit. *Lecidea* is as thoroughly crustaceous, but not so common as the *Buellia*. It must be noted that the latter plant shows locally the strong tendency to vary so characteristic of organisms attempting to adapt themselves to change in environment. Doubtless this variation has aided the plant somewhat in succeeding best of all the present or former more northern species of the locality against adverse climatic conditions. Whether or not the three forms of the species listed arose from one in this locality has no particular bearing in the matter as could be easily shown. Also the distribution of the three forms is so little known that knowledge as to which particular form is most common locally would not show whether it is one most commonly persisting in temperate regions or not.

It is interesting to note the time involved in the establishment of the Arctic flora and the change from this to the present essentially temperate flora. According to Professor N. H. Winchell's views as to the recession of St. Anthony falls, the final retreat of the glaciers from the region occurred about 8,000 years ago. Thus it seems that the succeeding 8,000 years must have sufficed for the establishment of a more or less rich Arctic flora and the gradual change to present floral conditions. The relative times involved in the establishment of the first flora and the gradual change to the present cannot be arrived at, since the richness of the first cannot be known, and we cannot yet be sure that a portion of the species migrating southward were not killed out in some portions of the series of migrations, so that some portion of the northern species that became established in the locality would have to migrate toward the center of the continent from the southward-extending mountains already mentioned. Light on this last supposition, which can only be fully obtained, it seems to me at present, by a study of the lichen flora of the British possessions far to the north of Minnesota, would be extremely interesting.

The absence of the 8 northern lichens from the sandstone may be easily explained, since it seems that the present sandstone surfaces exposed between Lake Superior and Taylors Falls are largely or entirely due to post-glacial erosion. If some of these surfaces are admitted to be as old as the time of the last glacial retreat, doubtless Arctic species grew on them at some time subsequent to that retreat. If this be true, it is yet easy to account for the failure of these lichens to persist on the sandstones as well as on the igneous rocks, since the lichen-flora of these porous and easily eroding surfaces must be a comparatively changeable and transient one, so that whatever such species once inhabited them would now be replaced by species more characteristic of present climatic conditions. After the final retreat of the ice and the change to present conditions of temperature and moisture began, the rapidly eroding surfaces would begin to lose their northern species and be resupplied by those at hand on other substrata at once, while those on igneous rocks could be replaced, mainly, at least, only by a fierce and long-continued struggle between the Arctic and temperate floral elements. The large number of species found on the sandstones is at first surprising, for while the igneous rocks are much richer in individual lichens, they show no appreciable advantage in species. The softer texture of the sandstone, which caused the more rapid destruction of the species growing under unfavorable climatic conditions, has also brought this condition. To be a little more explicit, while on account of their rapid erosion a large number of individuals cannot become established on them and remain long enough to constitute a flora rich in individuals, yet because of the porous character of the sandstone more of the species characteristic of temperate regions have doubtless already become established on them in one place or another than on the igneous rocks.

While the 8 species and varieties so fully treated above are of special interest there are some thoughts concerning the other 70 (excluding the last one listed) that must not be lost sight of. As to distribution they are a heterogeneous group, 30 of them being pretty generally distributed over the United States and Canada, 24 being limited so far as their distribution is known to the territory east of the Rocky mountains, 7 being thus far found only in the northern United States and Canada and 5 occurring throughout the United States. The North American distribution of the last 4 here considered is so little known that nothing can be definitely stated of it. Of these 70 all but 4 or 5 occur on rocks in some other portion of North America, but only 15 are strictly rupicoline. Of the other 55, some, though more characteristic of rocks, are more or less frequently found growing on other substrata; and others actually prefer other substrata and are growing on rocks here under unusually favorable conditions. These lichens, like the others, are of course the descendants of a race that has migrated several times. Nearly all of them being species also occurring in Europe, it is certain that they were represented by like species during early Tertiary times, far to the north where our continent was then connected with the Eastern continent on both sides. The coming of a cooler climate and finally of glacial conditions inaugurated the series of migrations. Finally after the last retreat of the glaciers began, the 55 species, because of their adaptation to more than one substratum, would follow the retreat more surely and more rapidly and thus more certainly and sooner reach a given locality and begin to replace a flora growing under unfavorable conditions. To just what extent the arctic flora would become established before these species would come in and begin to replace it can not be stated since the rate of retreat of the glaciers relative to the rate of migration of essentially stationary organisms is not known.

In the second paper of this series, I accounted for the comparative scarcity of lichens about Minneapolis by dryness of climate and stated that, were it not for peculiarly unfavorable conditions as to rock-formations, this explanation would require a larger per cent. of the total number of lichens found there to occur on the rocks because of greater amount of moisture near the ground. The annual precipitation at Osceola Mills for the last six years has been 31.271 inches, while at St. Paul it has been 28.997 inches. The former place being only seven miles from Taylors Falls, the figures may be taken to show that the precipitation in the locality now considered is about 2.274 inches more per annum than that at Minneapolis. Hence we have at Taylors Falls essentially the same conditions as to moisture of atmosphere as at Minneapolis. However at the former place we have the extensive rock-formations necessary for the establishment of the plants, and we find further that the igneous rocks are favorably situated for lichen development in that they lie along a river course formerly better shaded than now and where moisture has been abundant in spite of comparative dryness of atmosphere. Also this flora was doubtless largely established when the climate was not so dry as now and is persisting against conditions less favorable than formerly existed. Moreover the 8 persisting northern species add to the number strictly characteristic of present climate and give the locality a further advantage over Minneapolis and vicinity. Doubtless study of the whole lichen-flora about Taylors Falls would show that between 30 and 50 per cent. of the lichens grow on rocks as compared with 12 per cent. at Minneapolis. The slight advantage in annual precipitation of moisture for the former locality, of course, adds slightly to the relative richness in rock lichens, but this is insignificant as a cause when compared with the elements considered above.

Another objection of doubtful value to the first proposition suggested to account for the invasion of the northern rock-floral elements is that, though there is a continuous line of conifers from Lake Superior to Taylors Falls, the northern tree-inhabiting lichens are wholly absent at Taylors Falls, or so scarce as to escape notice. The coniferous trees are not so conspicuous a part of the flora at Taylors Falls as in Pine county, fifty miles north. No doubt at least a part of the tree lichens characteristic of more northern regions, and now almost certainly to be found in Pine county, have extended down to this location in post-glacial times, as the conifers are abundant from Lake

Superior down to the southern part of this county, and with substrata abundant, they could do so in spite of unfavorable climatic conditions. They have apparently failed to advance as far as Taylors Falls, because of favorite substrata becoming somewhat scarce, and an increase of unfavorable conditions as to temperature and precipitation. I am aware that the glaciers probably retreated slowly enough so that forests could spring up and furnish substrata for the retreat of species driven south in glacial times, before they would die out at the south on account of the return of warm climate, and that whatever northern tree lichens exist in the pineries fifty miles north, could be accounted for, wholly or in part, as having migrated from the south. Yet I am quite convinced that there has been a circulation of arboreous lichen-floral elements, between Lake Superior and Pine county, in post-glacial time, which has not extended to Taylors Falls, to any easily observable extent surely, though conditions as to substrata are much more favorable for such lichens to move southward from the lake than for the rock lichens.

Not a single species of northern lichen was found in the rock crevices or soil studied. I have noticed how in regions recently burned the soil becomes literally covered in places by lichens of various genera in five to fifteen years, and there can be no doubt that earth lichens took possession of the glacial drift rapidly after the retreat of the ice began. However, from the very fact that lichens spring up rapidly on earth, the species characteristic of temperate climate would the more quickly take possession of the present limited amount of soil available for lichen growth, and whatever additional amount that was available when the strife began between arctic and temperate earth lichens, and the more rapidly kill out the northern species once inhabiting the drift.

A consideration of the statements made in the last two paragraphs and various other portions of this paper points to the conclusion that a study of the whole lichen-flora of the area between Taylors Falls and Lake Superior is essential to a better understanding of the problems herein considered. In the next paper of this series, in which I shall consider the lichen-flora of the Lake Superior region, I shall be able to show additional reasons for the study of this territory. It is one of rapid transition in lichen-flora, and after a study of the areas to the north and south of it, questions of extreme interest have been suggested to me which can only be solved by a study of this flora.

The principal conclusions are as follows:

(1) The region considered in this paper is an important one for the study of lichen-flora because of position, and geological relations past and present.

(2) The flora considered is one of great interest as to origin and present composition and as to evidence of struggle between flora elements.

(3) The present lichen-flora is composed of arctic, sub-arctic and temperate florae elements in which the last have long since gained the advantage and are killing out the others.

(4) It is not supposed that the northern species migrated south in post-glacial times, but rather that this flora is one that followed the last retreat of the glaciers and was for a time essentially arctic, having since changed to its present composition.

(5) Reasons for the above conclusions are as follows:

(*a*) Southward migration would more naturally result from the decrease of temperature to the south inaugurated by the on-coming of a glacial climate and would thus go on even though suitable substrata might be somewhat scarce.

(*b*) But during the glacial advances rocky substrata were doubtless more numerous than now, a condition adding to the ease of migration.

(*c*) Under the influence of increasingly favorable climatic conditions to the south, the plants would take more easily to unfavorable substrata and migrate more readily on this account also.

(*d*) The 8 northern lichens are all but one essentially rock lichens and are, therefore, the ones that would be expected to persist longest.

(6) The northern floral elements considered may have been driven south during a late glacial advance not extending quite to the region, but more probably have been forced to migrate further south several times and migrate north as many times.

(7) The migrating plants may have been in part or wholly killed out in some part of the series of migrations southward in the Mississippi Valley, so that the present northern floral element would have to flow in from the mountains to the east and west, but more probably found sufficient substrata and were not killed out in the southward migrations in the valley.

(8) The time involved in the change from arctic and sub-arctic to temperate flora is probably about 8,000 years. The relative times occupied in the establishment of the northern flora and the change to the temperature one can not be estimated at present.

(9) The absence of the northern floral elements from the sandstone is due partly to the fact that many of the surfaces of sandstone exposures are post-glacial. If some are as old as the last retreat of the glaciers from the region, the absence is still easily explained since the surfaces are easily eroded and porous so that floral changes go on rapidly on these rocks.

(10) Lichens are not individually numerous on the sandstones because of this easily eroding nature which causes rapid change and destruction; yet a large number of species become established in one place or another on them because lichens quickly gain a foothold.

(11) The other 70 lichens of the rocks are not so characteristically rock lichens and would migrate more easily and rapidly, and the more quickly reach a locality and replace an established flora existing under unfavorable conditions, because not confined to one substratum.

(12) The rock lichen-flora of the locality is extremely rich because of abundance of rocks, location in a river valley where shade and moisture have been plentiful and geographically where the 8 northern species have persisted to increase the number more characteristic of present climatic conditions.

(13) In substantiation of the method used to account for the present composition of the flora, I have attempted to show that the absence of tree and earth lichens from the locality tends to prove its correctness.

(14) In view of work already done at Taylors Falls and along Lake Superior, the study of the region of rapid transition in lichen-flora between is greatly to be desired.

I am under great obligations to Dr. Charles P. Berkey for information concerning present and past geological conditions of the area studied. My thanks are also due to Professor Conway MacMillan for data concerning the distribution of the Conifers between Taylors Falls and Lake Superior and to Mr. Geo. H. Hazzard, of Taylors Falls, for the figures of annual precipitation of moisture in the vicinity of Taylors Falls.

LIST OF SPECIES AND VARIETIES.

1. **Ramalina calicaris** (L.) FR. var. **farinacea** SCHÆR.
On igneous rocks and sandstone, no. 83.

2. **Usnea barbata** (L.) FR. var. **florida** FR.
On igneous rocks and sandstone, no. 45.

3. **Usnea barbata** (L.) FR. var. **rubiginea** MICHX.
On sandstone, no. 117.

4. **Theloschistes lychneus** (NYL.) TUCK.
On igneous rocks and sandstone, no. 64.

5. **Theloschistes concolor** (DICKS.) TUCK.
On sandstone, no. 102.

6. **Parmelia perforata** (JACQ.) ACH.
On igneous rocks, no. 71.
Not previously reported from Minnesota.

7. **Parmelia crinita** ACH.
On igneous rocks, no. 66.

8. **Parmelia borreri** TURN.
On sandstone, no. 111.

9. **Parmelia saxatilis** (L.) FR.
On igneous rocks and sandstone, nos. 52 and 67.

10. **Parmelia olivacea** (L.) ACH.
On igneous rocks, no. 60.

11. **Parmelia caperata** (L.) ACH.
On igneous rocks and sandstone, no. 50.

12. **Parmelia conspersa** (EHRH.) ACH.
On igneous rocks and sandstone, no. 49.

13. **Physcia speciosa** (WULF. ACH.) NYL.
On igneous rocks and sandstone, no. 63.

14. **Physcia aquila** (Ach.) Nyl. var. **detonsa** Tuck.
On igneous rocks and sandstone, nos. 42 and 86.
Not previously reported from Minnesota.

15. **Physcia pulverulenta** (Schreb.) Nyl.
On igneous rocks and sandstone, no. 73.

16. **Physcia stellaris** (L.) Tuck.
On igneous rocks, no. 2.

17. **Physcia tribacia** (Ach.) Tuck.
On igneous rocks, nos. 55 and 77.

18. **Physcia cæsia** (Hoffm.) Nyl.
On igneous rocks, no. 30.

19. **Physcia obscura** (Ehrh.) Nyl.
On igneous rocks, nos. 5 and 47.

20. **Pyxine sorediata** Fr.
On igneous rocks, no. 48.

21. **Umbilicaria dillenii** Tuck.
On igneous rocks, no. 87.

22. **Nephroma helveticum** Ach.
On igneous rocks, no. 26.
Not previously reported from Minnesota.

23. **Peltigera pulverulenta** (Tayl.) Nyl.
On earth among igneous rocks, no. 15.

24. **Peltigera rufescens** (Neck.) Hoffm.
On earth among igneous rocks, no. 17.

25. **Peltigera canina** (L.) Hoffm.
On earth among igneous rocks and on sandstone, nos. 16 and 28.

26. **Peltigera canina** (L.) Hoffm. var. **spuria** Ach.
On sandstone, no. 119.

27. **Peltigera canina** (L.) Hoffm. var. **sorediata** Schær.
On sandstone, no. 96.

28. **Pannaria languinosa** (Ach.) Koerb.
On igneous rocks and sandstone, no. 20.

29. **Pannaria microphylla** (Sev.) Delis.
On igneous rocks and sandstone, no. 35.
Not previously reported from Minnesota.

30. **Ephebe solida** Born. (?)
On igneous rocks, no. 59.
The specimens were sterile and must be regarded as uncer-

tain as to species. I found the same plant in three or four localities in northern Minnesota.

Not previously reported from Minnesota.

31. **Collema pulposum** (BERNH.) NYL.
On earth among igneous rocks, no. 23.

32. **Collema flaccidum** ACH.
On igneous rocks, no. 43.

33. **Leptogium tremelloides** (L. FIL.) FR.
On igneous rocks, nos. 18, 25, 29 and 61.
Not previously reported from Minnesota.

34. **Leptogium chloromelum** (SEV.) NYL.
On sandstone, no. 109.
Not previously reported from Minnesota.

35. **Placodium elegans** (LINK.) DC.
On igneous rocks and sandstone, no. 53.

36. **Placodium cinnibarinum** (ACH.) ANZ.
On igneous rocks, no. 31 and 62.

37. **Placodium aurantiacum** (LIGHT) NAEG. and HEPP.
On igneous rocks and sandstones, no. 57.
A form with scanty thallus and biatorine apothecia, appearing much like the next.

38. **Placodium cerinum** (HEDW.) NAEG. and HEPP. var. **sideritis** TUCK.
On igneous rocks, nos. 38, 39 and 91.

39. **Placodium vitellinum** (EHRH.) NAEG. and HEPP.
On igneous rock and sandstone, no. 3.

40. **Lecanora rubina** (VILL.) ACH.
On igneous rocks and sandstone, no. 51.

41. **Lecanora subfusca** (L.) ACH.
On igneous rocks and sandstone, nos. 12 and 115.

42. **Lecanora subfusca** (L.) ACH. var. **coilocarpa**, ACH.
On sandstone, no. 108.

43. **Lecanora atra** (HUDS.) ACH. (?)
On igneous rocks, no. 4.
Not previously reported from Minnesota.

44. **Lecanora hageni** ACH.
On sandstone, no. 118.

45. **Lecanora varia** (EHRH.) NYL.
On igneous rocks and sandstone, no. 68.

46. **Lecanora varia** (EHRH.) NYL. var. **symmicta**, ACH.
On sandstone, no 103.

47. **Lecanora cinerea** (L.) SOMMERF.
On igneous rocks and sandstone, nos. 11, 19, 34 and 70.

48. **Lecanora cinerea** (L.) SOMMERF. var. **lævata**, FR.
On igneous rocks, no. 14.
Not previously reported from Minnesota.

49. **Lecanora fuscata** (SCHRAD.) TH. FR.
On igneous rocks and sandstone, nos. 33, 56, 94, and 106.
Not previously reported from Minnesota.

50. **Rinodina sophodes** (ACH.) NYL.
On igneous rocks and sandstone, nos. 59 and 105.

51. **Pertusaria velata** (TURN.) NYL.
On sandstone, no. 95.

52. **Pertusaria communis** DC.
On sandstone, no. 112.

53. **Urceolaria scruposa** (L.) NYL.
On igneous rocks and sandstone, no. 9.

54. **Stereocaulon condensatum** HOFFM.
On sandstone, no. 93.
Not previously reported from Minnesota. Also not listed before west of New England.

55. **Cladonia mitrula** TUCK.
On sandstone, no. 99.

56. **Cladonia cariosa** (ACH.) SPRENG.
On sandstone, 114.

57. **Cladonia pyxidata** (L.) FR.
On earth among igneous rocks, no. 65.

58. **Cladonia squamosa** HOFFM.
On earth among igneous rocks, nos. 72 and 78.
Not previously reported from Minnesota.

59. **Cladonia cæspiticia** (PERS.) FL.
On earth among igneous rocks and on sandstone, nos. 68^a and 101.

60. **Cladonia fimbriata** (L.) FR. var. **tubæformis** FR.
On sandstone, nos. 104 and 110.

61. **Cladonia gracilis** (L.) NYL.
On earth among igneous rocks and on sandstone, no. 74.

62. **Cladonia gracilis** (L.) NYL. var. **verticillata**, FR.
On sandstone, no. 116.

63. **Cladonia delicata** (EHRH.) FR.
On old wood among igneous rocks, nos. 79[a] and 67.
Not previously reported from Minnesota.

64. **Cladonia rangiferina** (L.) HOFFM.
On earth among igneous rocks, no. 81.

65. **Cladonia rangiferina** (L.) HOFFM. var. **alpestris** L.
On earth among igneous rocks, no. 82.

66. **Cladonia macilenta** (EHRH.) HOFFM.
On old roots among igneous rocks, no. 79[b] and 80[a].

67. **Biatora rufonigra** TUCK.
On igneous rocks, no. 1.
Not previously reported from Minnesota.

68. **Biatora coarctata** (SM. NYL.) TUCK. var. **brajeriana** SCHÆR.
On sandstone, no. 92.
Not previously reported from Minnesota.

69. **Biatora myriocarpoides** (NYL.) TUCK.
On sandstone, no. 100. Habitat unusual, but I cannot distinguish sufficiently between this and my wood specimens to separate them.
Not previously reported from Minnesota.

70. **Lecidea albocærulescens** (WULF.) SCHÆR.
On igneous rocks and sandstones, no. 27.
Not previously reported from Minnesota.

71. **Buellia spuria** ARN.
On igneous rocks, no. 22.
Not previously reported from Minnesota.

72. **Buellia petræa** (FLOT., KOERB.) TUCK.
On igneous rocks, no. 58.
Not previously reported from Minnesota.

73. **Buellia petræa** (FLOT., KOERB.) TUCK. var. **montagnæi** TUCK.
On igneous rocks, no. 89.
Not previously reported trom Minnesota.

74. **Buellia petræa** (FLOT., KOERB.) TUCK. var. **grandis** FLOERK.

On igneous rocks, no. 89^a. Thallus coarser, more crowded and lighter colored. Hypothallus deficient.

Not previously reported from Minnesota.

75. **Endocarpon miniatum** (L.) SCHÆR.
On igneous rocks and sandstone, no. 41.

76. **Endocarpon hepaticum** HEDW.
On sandstone, no. 97.

77. **Verrucaria fuscella** FR.
On igneous rocks, no. 21.

78. **Verrucaria muralis** ACH.
On sandstone, no. 107.

79. **Thelocarpon prasinellum** NYL.
On old boards, no. 113.
Not previously reported from Minnesota.

II. A METHOD OF DETERMINING THE ABUNDANCE OF SECONDARY SPECIES.

ROSCOE POUND AND FREDERIC E. CLEMENTS.

In determining the abundance of species, appearances are extremely deceptive. One who has worked over the prairies for many seasons comes to think that he can pick out instantly the most abundant secondary species. Long continued observation in the field stamps a picture on one's mind, and it seems a simple matter to pick out the several species and to classify them in the several grades of abundance with reasonable accuracy. As a matter of fact, this is not possible. After more than ten years of active field work on the prairies, it seemed to the writers that the mental pictures acquired was approximately sufficient to make the reference of the commoner secondary species of prairie formations to their proper grades an easy task. When actual looking at the prairies as the season permitted appeared to confirm the picture already formed, this seemed certain. Closer analysis of the floral covering proved that the conclusions formed from looking at the prairie formations and from long field experience, without actual enumeration of individual plants, were largely erroneous. The psoraleas, prairie clovers and blazing stars would probably occur to all as among the most abundant of the secondary species in the vernal, estival and serotinal aspects of the prairies respectively. When we first addressed ourselves to the task of assigning to each of the various prairie species its proper degree of abundance, it occurred to us at once that we could take a certain species, or certain species, as types for each grade, and use these species as standards by which to measure the others. It proved in the end that the species selected, though of the commonest occurrence and hence familiar from daily observation, were in many cases referred to wrong grades as compared with other species, no less common, but for some reason not so prominent. The difficulty is that the species which appear most prominent in the constitution of the prairies are not necessarily the most abundant.

The prominent-flowered blazing stars and prairie clovers make a much greater impression on the eye than species which are far more abundant, and the same thing is true to a less degree of many other species. To insure accurate or even approximately accurate results, it is necessary to resort to some method of actual count.

Actual count is usually practicable only when copious, gregario-copious or sparse plants are in question. But it is only with respect to such species, which are as a rule secondary in formations, that it is important to determine minutely the grade of abundance manifested.

During the past season, in order to determine the actual quantitative relations of the copious and gregario-copious species, we have made a large number of enumerations of the individual plants of each secondary species present in plots five meters square in characteristic formations of each of the four phytogeographical regions represented in Nebraska. The plot used, five meters square, is as large as can be used to insure accuracy in counting. The deficiences resulting from the small size of the plots are corrected by taking a large number of plots at each station and averaging the results. There is a surprisingly close agreement in figures obtained from plots in widely separated stations in the same district, provided reasonable care is taken to locate them in typical situations.

By way of illustration, a number of observations are given in full. These are not averages, but are the actual counts as taken in the field. The two immediately following were taken on the prairie 14 miles northeast of Lincoln in the prairie grass formation (*Sporobolus-Koeleria-Panicum*). The second was made about 400 yards distant from the first.

Amorpha canescens	387
Aster multiflorus	223
Antennaria campestris (16 patches)	209
Solidago rupestris	101
Helianthus rigidus	97
Kuhnistera candida	43
Kuhnistera purpurea	31
Brauneria pallida	24
Solidago rigida	19
Kuhnia glutinosa	8
Comandra umbellata	7
Rosa arkansana	2

(2)

Amorpha canescens	368
Aster multiflorus	395
Antennaria campestris (6 patches)	154
Solidago rupestris	105
Helianthus rigidus	63
Kuhnistera candida	26
Kuhnistera purpurea	22
Brauneria pallida	19
Solidago rigida	16
Rosa arkansana	8
Solidago rigidiuscula	5
Gerardia purpurea	3
Laciniaria scariosa	2
Erigeron ramosus	1

Linum rigidum was prominent, but did not occur in either of the plots, and in comparatively few of those laid out.

In a large number of plots, *Amorpha canescens* averaged 309, *Aster multiflorus* 275, and *Antennaria campestris* 12 patches and 145 individuals.

Enumerations were also made in the same formation in the transition area between the prairie region and the sand hill region. The following example is one of a number made south of Broken Bow (Custer County). The formation is the ordinary prairie grass (*Sporobolus-Koeleria-Panicum*) formation, modified somewhat on account of the sandy soil.

Amorpha canescens	291
Aster multiflorus	238
Kuhnistera candida (?)	23
Solidago rupestris	21
Brauneria pallida	17
Helianthus rigidus	12
Kuhnia glutinosa	5

The marked decrease in the number of secondary species and in the abundance of each is characteristic of this transition area.

Another count, made where the prairie grass formation was giving way to the buffalo grass formation on the one hand, and to the bunch grass formation on the other, is interesting. While the prairie grasses (species of *Sporobolus*, *Koeleria cristata* and *Panicum Scribnerianum*) were controlling, there was a strong admixture of *Bouteloua oligostachya*, and two bunches of *Andropogon scoparius* occurred in the plot. The locality was about six miles northwest of the preceding.

Amorpha canescens	192
Kuhnistera occidentalis (?)	26
Solidago rupestris	18
Artemisia gnaphalodes	17
Solidago mollis	12
Solidago rigida	3
Helianthus rigidus	2

The following count, made in the buffalo grass formation, about two miles beyond the one last set forth, shows the latter formation as affected by the near proximity of the prairie gras, formation. The number of secondary species, small as it is, is very large for that formation. Where this count was mades the dominant grass was *Bouteloua oligostachya*. The only other grass was *Schedonnardus paniculatus*, represented by two small patches.

Plantago Purshii	42
Solidago mollis	23
Lygodesmia juncea	5
Lepachys columnaris (dwarf)	3
Eriocarpum spinulosum	2
Grindelia squarrosa	1
Kuhnia glutinosa	1
Lesquerella argentea	1

The constant diminution in the number and abundance of secondary species as one passes from the prairie grass formation of the prairie region to the buffalo grass and bunch grass formations of the transition area and of the sand hill region is well illustrated by these figures. The difference betweeen the prairie grass formation in its ordinary situations and in the transition area, and between the buffalo grass formation of the "range" and the same formation in the transition area is better shown by figures obtained from such enumerations than in any other way. Many other examples of the efficacy of this method in representing changes in the floral covering as one passes from one district to another might be given.

The method of actual enumeration of the individual plants present in plots of a given size makes accurate limitation of the several grades of abundance possible. Of course, this has nothing to do with the mode of disposition of individuals. But given a copious, gregario-copious or sparse species, there still remains something more to be said before the abundance of the species is fairly indicated. Collation of the results of a large number of enumerations has shown that six grades of copious plants may be recognized readily. The first, in which the average number of individuals in a plot five meters square exceeds 200, corresponds to copious.[1] As examples, there may be cited from the prarie formations *Amorpha canescens*, with an average of 309 in the prairie region, *Aster multiflorus* with an average of 275 in the prairie region and about 230 in the sand hill region; from the herbaceous layer of woody formations, *Verbesina alternifolia* (which is almost gregarious at times), with an average of 245. To the second degree (copious[2]) those species may be assigned in which the average number of individuals in a plot is from 150 to 200, such as *Plantago Purshii* (162) in the Peppergrass-Cactus formation in the transition area between the sand hill region and the foot hill region. Those species with an average ranging from 100 to 150 may be assigned to the third degree (copious[3]). Examples are: *Aster sagittifolius*, which has an average of 133 in the herbaceous layer of the Bur-oak-Elm-Walnut formation in the Mississippi basin region and *Solidago rupestris*, which has an average of 104 in the *Sporobolus-Koeleria-Panicum* formation in the prairie region. In the fourth degree (copious[4]) those species may be included which have an average of from 50 to 100, such as *Glycorhiza lepidota* in the river valleys in the sand hill region, where its average is 83. All of the foregoing are of sufficient abundance to be included in the general term "copious," taking the latter to represent a quantitative idea as well as the manner of association of the individuals. Where the average falls below 50 and exceeds 5, we call the species "subcopious." Comparison and collation of statistics has shown that subcopious species fall into two groups, in one, which we call subcopious,[1] the average does not fall below 15. Examples are: *Kuhnistera candida* in the *Sporobolus-Koeleria-Panicum* formation in the prairie region, where it has an average of 18, *Solidago mollis* in the Peppergrass-Cactus formation in the transition area between the sand hill and foot hill regions, where its average is slightly over 20, and *Artemisia gnaphalodes* in the transition between the prairie and the sand hill regions, where its average is 16.

Where the average number in a plot is between 5 and 15, the species is called subcopious.[2] A glance at the list given above will show that these are often very striking components of the prairie formations. Finally, in case the average is below 5 and above .01, or one individual in ten plots, the species is called "sparse." Gregario-copious species may be treated in the same way, giving gregario-copious,[1] etc. *Antennaria campestris* in the prairie grass formations of the prairie region, averaging 12 patches and 145 individuals per plot, would be gregario-copious.[3]

Although this method involves no little labor, especially when applied to social species, as we have been able to do successfully in some cases, such as the Peppergrass in the Peppergrass-Cactus formation, it has furnished results which amply reward the time and work required. By means of such enumerations we have been able to determine many questions with certainty which could only be guessed at otherwise, and we have been able to make more accurate limitations of the regions and particularly the transition areas than we had thought possible.

III. LIST OF FRESH-WATER ALGAE COLLECTED IN MINNESOTA DURING 1896 AND 1897.

JOSEPHINE E. TILDEN.

During the past two years no special effort has been made to collect the algae of the State. Several species have been given particular study in the laboratory and a few others have incidentally been brought to notice. The list comprises only those not heretofore recorded in Minnesota, and is a continuation of the series begun in Vol. I. of this publication. Attention may be called to the comparatively large number of lime-secreting forms.

HELMINTHOCLADIACEÆ (HARV.) SCHMITZ Syst. Uebers. Florid. in Flora 4. 1889.

240. **Chantransia pygmaea** (KG.) SIRDT. Les Batrachospermes. 244, 245. 1884.

Together with *Chaetophora calcarea*, *Dicothrix calcarea*, *Lyngbya martensiana* var. *calcarea* and *L. nana*, forming the calcareous crust on sides of old tank and on twigs in the water.

Minneapolis, Minnesota. October 1, 1895.

241. **Chantransia expansa** WOOD. Contr. Hist. Fresh-Water Algae North Am. 215. pl. 19. f. 2. 1872.

On stones under waterfall. Osceola, Wisconsin. September 15, 1897.

CHARACEAE RICHARD in Humb. et Bonpl. Nov. G. I. 1815.

242. **Chara contraria** A. BR. Schweizer. Char. 15. 1847.

In ditches. Osceola, Wisconsin. August 31, 1895.

243. **Chara foetida** A. Br. Ann. Sci. Nat. Bot. II. 1: 354. 1834.

In pool formed by spring water. Osceola, Wisconsin. September 15, 1897.

ULOTRICHIACEAE (KG.) BORZI em. DE TONI. Syll. Alg. **1**: 151. 1889.

244. **Hormiscia zonata** (WEB. and MOHR) ARESCH. var. **valida** (NÄG.) RABENH. Fl. Eur. Algar **3**: 362. 1868.

On rocks wet with surf. Grand Marais, Lake Superior, Minnesota. Coll. A. H. Elftman. July 27, 1896.

PALMELLACEAE (DECNE.) NÄG. em. DE TONI. Syll. Alg. **1**: 559. 1889.

245. **Scenedesmus obliquus** (TURP.) KG. Syn. Diat. in Linnaea. **8**: 609. 1833.

Grown in aquarium in which water was saturated with nitrous oxide. University of Minnesota, Minneapolis, Minnesota. Emil Sandsten. February 23, 1898.

246. **Chlorochytrium archerianum** HIERON. in Jahres. Schles. Gesellsch. 296. 1887.

In cells of *Sphagnum* which had been kept in the University plant-house six weeks. Osceola, Wisconsin. Coll. Conway MacMillan. September 15, 1896.

247. **Tetraspora cylindrica** (WAHLENB.) AG. Syst. Alg. 188. no. 2. 1824.

Attached to lake bottom, abundant around the outside harbor rocks. Grand Marais, Lake Superior, Minnesota. Coll. A. H. Elftman. July 27, 1896.

248. **Palmella miniata** LEIBL. var. **aequalis** NÄG. Einzell. 67. pl. 4. D. f. 2. 1849.

On submerged rocks and pebbles in slow current. Minnehaha creek, Soldiers' Home, Minneapolis, Minnesota. September 27, 1896.

This species contains calcium carbonate in quantity. It is accompanied by filaments which much resemble *Stigeoclonium* in its transition stage.

ZYGNEMACEAE (MENEGH.) RABENH. Fl. Eur. Algar. **2**: 228. 1868.

249. **Mougeotia parvula** HASS. var. **angusta** (HASS.) KIRCHN. Alg. Schles. 128. 1878.

Grown in aquarium in which water was saturated with nitrous oxide. University of Minnesota, Minneapolis, Minnesota. Emil Sandsten. February 23, 1898.

RIVULARIACEAE RABENHORST Fl. Eur. Algar. 2: 2. 1865.

250. **Calothrix parietina** (NÄG.) THUR. Ess. Class. Nostoch. in Ann. Sci. Nat. Bot. VI. **1**: 381. 1875.

On stone sides of fountain, breaking up in small fragments when peeled off. Kenwood, Minneapolis, Minnesota. August 3, 1895.

251. **Dichothrix calcarea** TILDEN Am. Alg. Cent. II. no. 165. 1896. Bot. Gaz. **23**: 95–104. pl. 7–9. F. 1897

Forming a part of the lime incrustation which covers sides of wooden tank. With no. 240. Minneapolis, Minnesota. October 1, 1895.

252. **Rivularia biasolettiana** MENEGH. in Zanardini Syn. Alg. in mari Adriatico collect. in Reale Acad. Sci. Torino. II. IV. 42. 1841.

On rocks at edge of lake. Big Stone lake, Dakota. Coll. David Griffiths. October 4, 1895.

253. **Gloeotrichia pisum** (AG.) THURET. Essai de class. Nostochinées in Ann. Sci. Nat. Bot. VI. 1: 382. 1875.

Floating on surface of water in large quantity. Lake Minnewaska, Glenwood, Minnesota. Coll. Elizabeth H. Foss. August, 1897.

NOSTOCEAE KÜTZ Phyc. gen. 203. 1843.

254. **Anabaena azollae** STRASB. Bot. Prakt. 341. f. 130. 1887.

In chambers in the leaves of *Azolla Caroliniana*. University plant-house, Minneapolis, Minnesota. September 15, 1896.

255. **Anabaena cycadearum** REINKE, Bot. Zeit. **37**: 473–476. pl. 6. f. 1–5. 1879.

In roots of *Cycas revoluta*. University plant-house, Minneapolis, Minnesota. December 20, 1896.

256. **Anabaena flos-aquae** (LYNGB.) BRÉB. in Brébisson et Godey. Algues des environs de Falaise. 36. 1835.

Floating in abundance on surface of water. Cedar lake, Hennepin county, Minnesota. Coll. Miss M. G. Fanning and H. B. Humphrey. October 28, 1897.

VAGINARIEAE Gomont in Morot, Journ. de Bot. **4**: 351. 1890.

257. **Schizothrix rupicola** Tilden. Am. Alg. Cent. II. no. 175. 1896. Bot. Gaz. **23**: 95–104. pl. 7–9. F. 1897.

Bare and dry sandstone cliffs. Soldiers' Home, Minnehaha Falls, Minnesota. Coll. C. W. Hall. September 28, 1896.

258. **Schizothrix lardacea** (Cesati) Gomont. Monogr. des Oscill. in Ann. Sci. Nat. Bot. VII. **15**: 311. pl. 8. f. 8, 9. 1892.

In a large bottle of distilled water left standing for several months. Botanical laboratory, University of Minnesota, Minneapolis, Minnesota. 1896. Det. by Gomont.

LYNGBYEAE Gomont Ess. class des Nostocacées homocystées in Morot Journ. de Bot. **4**: 353. 1890.

259. **Lyngbya martensiana** Menegh. var. **calcarea** Tilden. Am. Alg. Cent. II. no. 178. 1896. Bot. Gaz. **23**: 95–104. pl. 7–9. F. 1897.

With no. 240. Minneapolis, Minnesota. October 1, 1895.

260. **Lyngbya nana** Tilden. Am. Alg. Cent. II. no. 179. 1896. Bot. Gaz. **23**: 95–104. pl. 7–9, F. 1897.

With no. 240. Minneapolis, Minnesota. October 1, 1895.

261. **Phormidium valderianum** (Delp.) Gomont Monogr. des Oscill. in Ann. Sci. Nat. Bot. VII. **16**: 167. pl. 4. f. 20. 1892.

In arm of Mississippi river (old channel), St. Paul Park, Minnesota. Coll. E. M. Freeman, October 3, 1897.

With *Oscillatoria geminata*, *O. tenuis* var. *tergestina*, *Phormidium valderianum*, and species of *Chroococcus*, Palmellaceae, *Coccochloris*, *Rhaphidium*, *Polycystis* and *Scenedemus*. Det. by Gomont.

262. **Oscillatoria geminata** Menegh. Consp. Algol. euganeae. 9. 1837.

With no. 261.

263. **Oscillatoria tenuis** Agardh. Alg. Dec. 2:25. 1813.
With no. 261.

264. **Gloeocapsa calcarea** n. sp.
Forming a calcareous crust, light gray to light aeruginous in color, 2–3 mm. in thickness; cells 6–9 mic. in diameter, 4–16 united in families; families 25–50 mic. in diameter; sheath colorless, somewhat thin; cell-contents aeruginous, granular.
Associated with several other lime-secreting algal forms.
On boards where spring water from trough drips down constantly. Osceola, Wisconsin. September 15, 1897.

IV. CORRECTIONS AND ADDITIONS TO THE FLORA OF MINNESOTA.

A. A. HELLER.

Chenopodium Boscianum MOQ. Enum. Chenop. 21. 1840.

This species should be stricken from the list of Minnesota plants, as no specimen of it has yet been reported from the State. Sheldon's "1555, Lake Benton," as well as specimens from other localities, quoted in the Metaspermæ of the Minnesota Valley, probably belong to *Chenopodium album*.

Sophia pinnata (WALT.) BRITTON, Ill. Fl. 2: 145. 1897.

Erysimum pinnatum WALT. Fl. Car. 174. 1788.
Sisymbrium canescens NUTT. Gen. 2: 68. 1818.
Descurainia pinnata BRITTON, Mem. Torr. Bot. Club, 5: 173. 1894.

The plants referred to this species in the Metaspermæ of the Minnesota Valley, under the name of "*Sisymbrium multifidum*," belong to *Sophia incisa*, with the exception of Sheldon's "1406, Lake Benton," and "Taylor, 1044, Glenwood," which are specimens of *Sophia Hartwegiana*. *Sophia pinnata* does not occur in Minnesota.

Potentilla leucocarpa RYDBERG, in Ill. Fl. 2: 212. 1897.

To this species belongs the specimen collected by Sheldon at Fergus Falls, Otter Tail county, August, 1892, and referred by him to *Potentilla Nicolletii*. Another specimen, also collected by Sheldon, and determined as *P. Nicolletii*, was obtained at Silver Lake, Otter Tail county, September, 1892.

Potentilla Monspeliensis L. Sp. Pl. 499. 1753.

A specimen of this was collected at Pelican Lake, Otter Tail county, August, 1892, by Sheldon, but referred to *Potentilla Nicolletii*, in Minn. Bot. Stud. 1: 16.

Potentilla Nicolletii (WATS.) SHELDON, Minn. Bot. Stud. **1**: 16. 1894.

Potentilla supina var. *Nicolletii* WATS. Proc. Am. Acad. **8**: 553. 1873.

As shown by the two preceding notes, this species does not occur in Minnesota, for the specimens upon which Mr. Sheldon raised the variety to specific rank, belong to another species, or rather to two species.

Potentilla pentandra ENGELM.: T. & G. Fl. N. A. **1**: 447. 1840.

Not previously reported from Minnesota. Collected at Jordan, Scott county, June, 1891, by C. A. Ballard, no 252. In the Metaspermæ of the Minnesota Valley, this specimen is referred to *Potentilla Canadensis*, a species which it does not at all resemble.

Malus Ioensis (WOOD) BRITTON, Ill. Fl. **2**: 235. 1897.

Pyrus coronaria var. *Ioensis* WOOD, Class Book, 333. 1860.
Pyrus Ioensis BAILEY, Am. Gard. **12**: 473. 1891.

In the Metaspermæ of the Minnesota Valley this species is included under "*Pirus coronaria*," and the following specimens cited there belong to it, and not to *Malus coronaria*: Ballard, 345, Helena, Scott County; Sheldon, 659, Waseca; Sandberg, Red Wing. Sheldon's 322, Smith's Mills, Blue Earth county, may belong here, but the specimen is so mutilated and imperfect that accurate determination from it alone is not possible.

Geranium Bicknellii BRITTON, Bull. Torr. Bot. Club, **24**: 92. 1897.

Apparently common in Minnesota, as evinced by the following collections: J. H. Sandberg, Taylor's Falls, Two Harbors, Red Wing; C. L. Herrick, Minneapolis, St. Louis river; F. F. Wood, Pike Lake; L. H. Bailey, Vermilion Lake, no. 199; T. S. Roberts, Duluth; C. A. Ballard, Prior's Lake, Cleary's Lake, Scott county; B. C. Taylor, Alexandria, Taylor's Falls; Otto Lugger, Tower; E. P. Sheldon, Milaca, Mille Lac Reservation, Nichols. It has heretofore been confused with *Geranium Carolinianum*, but that species does not seem to have been collected in Minnesota, as no specimens from the State are found in the herbarium of the University.

Lechea stricta LEGGETT; Britton, Bull. Torr. Bot. Club, 21: 251. 1894.

The Illustrated Flora gives the range of this species as "Wisconsin, Illinois, Iowa." It has also been collected at several localities in Minnesota. We have two specimens collected by J. H. Sandberg, one at Sandy Lake, August, 1891, labeled "*Lechea minor*," the other at Centreville, July 30, 1891, labeled "*Lechea Leggettii*." There is also a specimen collected at Zumbrota, August, 1892, by C. A. Ballard, labelled "*Lechea Leggettii*," and one collected by Miss Jennie E. Campbell, at Rockville, July, 1896. E. P. Sheldon also collected it at St. Croix Falls, Wisconsin, September, 1892.

The type of this species was presumably collected by Mr. M. S. Bebb, as we have a specimen from his collection, with the record: "*Lechea stricta*, Leggett ms. . . . Fountaindale, Winnebago County, Illinois, 1879." By referring to the Botanical Gazette, **15**: 308. 1890, I find that the species was reported from Minnesota, previous to its publication, by E. J. Hill, who says: "The only *Lechea* seen was one called by Mr. W. H. Leggett, who has given special attention to these plants, *L. minor* Lam. var *stricta*. It grows on sandy hills, especially those thinly covered with *Pinus Banksiana* and *P. resinosa*, where the ground is not too much shaded, and on rocky hills and ledges with a thin covering of soil, on top of which, Jasper Peak, the highest point in the vicinity of Tower, I find it common."

V. NEW AND INTERESTING SPECIES FROM NEW MEXICO.

A. A. HELLER.

Allionia diffusa n. sp.

Stems terete, two or three from a perennial rootstalk, diffusely branched from the base, 20 to 30 cm. in length, whitened and glabrous below, the middle part usually marked with several lines of short, curved hairs, the branches immediately below the inflorescence, as well as the inflorescence itself, covered with spreading, glandular hairs; leaves sessile, lanceolate-linear, slightly narrowed at the base, the lowest 5 to 6 cm. long, the upper ones about half that length, all acute, the upper face provided with a grayish margin, midvein prominent; involucres clustered at the ends of the branches, mature ones about 7 mm. across, their lobes triangular-lanceolate, acutish, between 2 and 3 mm. long; perianth pale rose color, 6 mm. long, its lobes broadly obovate; stamens three, these, as well as the style, exserted.

The type is our no. 3740, collected June 21, 1897, on dry, gravelly hills, ten miles west of Santa Fé, altitude 6000 feet. The diffuse habit of the plant cannot always be well shown in dried specimens, but it is quite marked in the living state, the lower branches being almost procumbent. This species is, perhaps, plentiful in the vicinity of the place where it was first found, but as only one trip was made to that place after it came into bloom, only a few specimens were collected.

Pedicularis fluviatilis n. sp.

Stems several from a perennial root, erect, 15 to 20 cm. high, lanate pubescent, especially above, leafy, or the upper part somewhat naked; leaves alternate, rather distant, dark green, mature ones 5 to 6 cm. long, 1 cm. wide, linear-oblong in outline, acute or acutish, deeply pinnately parted, the lobes of almost uniform width, and lobed or serrate with spreading teeth; spikes leafy bracteate, dense, 4 to 6 cm. long, and almost as broad; calyx 1 cm. long, obliquely cleft to the base on the lower side, the upper side notched with a shallow rounded sinus; corolla lemon yellow or faintly purple tinged, slightly over 2 cm. in length, 6 mm. wide, summit of the galea incurved, the tip provided with two cusps.

The type is our no. 3639, collected June 2, 1897, in a meadow nine miles east of Santa Fé, altitude 8000 feet. The name *fluviatilis* is not very appropriate, but as specimens have been distributed under this name, I consider it better policy to describe it under the name it has borne, rather than cause confusion by assigning another more appropriate one. The specimens were growing in a grassy meadow, on the banks of the Santa Fé creek, opposite "Monument Rock." For some months of the year this meadow is overflowed by water from an irrigating ditch, so that then the plants are actually growing in water, as indicated by the name. This species seems to be closely related to the common eastern *P. Canadensis.*

Pentstemon caudatus n. sp.

Glabrous throughout; stems herbaceous, rather stout and fleshy, simple, erect, 25 to 30 cm. high, pruinose, leafy throughout; leaves all sessile, more or less clasping, pruinose, rather fleshy, margined with a narrow pale line, the lower ones spatulate-oblong, or oblong-lanceolate, moderately acute, 4 to 7 cm. long, 5 mm. to 1 cm. wide, gradually becoming longer and broader until the inflorescence is reached, where they are broadly ovate-lanceolate, with long and narrow tips; beginning with the inflorescence they become gradually shorter, but still retain the broad base, until near the very end of the stalk, where they are reduced to lanceolate bracts: flowers pale violet or pinkish, numerous in thyrsiform close clusters in the axes of the leaves, occupying from one-half to three-fourths of the length of the stem: calyx about 5 mm. long, its lobes lanceolate, or ovate-lanceolate, long-pointed, scarious margined, broadly so near the base; corolla slightly over 2 cm. in length, the tube gradually dilated into the funnelform throat, the orbicular-obovate lobes nearly equal, about 7 mm. long, spreading; sterile filament bearded in the upper half on one side, the tip somewhat dilated and curled; anthers dehiscent from base to apex, puberulous at line of dehiscence.

The type is our no. 3580, collected May 26, 1897, at Barranca, Taos county, altitude 6900 feet. It is very abundant in open grassy, sandy soil, about Barranca station, growing in large patches. This species is likely to occur in Colorado also, as it occurs on the plateau which runs up into Colorado between the two mountain ranges, and specimens of it will probably be found in herbaria under the name of *P. acuminatis* Dougl., which northwestern species seems to be a convenient depository for anything which at all remotely resembles the original.

Senecio Sanguisorbæ DC. Prodr. 6: 427. 1837.

Specimens referable to this species were collected in Santa Fé Cañon, about twelve miles from Santa Fé. They were growing in wet ground along the stream, at a place well within the woods. Although numerous plants were seen, only a few specimens were obtained, as it was just coming into bloom and that part of the Cañon was not again visited. To the best of my knowledge, the species has not hitherto been recorded within the borders of the United States. No. 3820.

Sitilias Rothrockii (A. GRAY) GREENE, Pittonia, 2: 180. 1891.
Pyrrhopappus Rothrockii A. GRAY, Proc. Am. Acad. 11: 80. 1876.

In our distribution of New Mexican plants of 1897, this species was erroneously determined as "*Sitilias multicaulis* (DC.) GREENE." It was collected in a meadow along the Rio Grande river opposite the Indian Pueblo of San Juan, no. 3758. The specimens were obtained either in damp ground, or sometimes actually in water in swampy places. In some of the specimens the leaves are entire, or the lower ones only slightly toothed, while in others the lower ones are conspicuously pinnatifid. The original came from "Fisch's Ranch, in southern Arizona, at 5000 feet altitude." Rothrock, 699.

The type-specimens are deposited in the herbarium of the University of Minnesota.

VI. SOME MUSCI OF THE INTERNATIONAL BOUNDARY.

John M. Holzinger.

The mosses listed below were personally collected during the summer of 1897 in northeastern Minnesota along the Dawson canoe-route between Ely and Grand Portage. The route includes the following lakes: Fall, Basswood, Newton, Sucker, Carp, Melon, Seed, Knife, Otter-track, Saganaga, Granite, Gunflint, North, South, Rose, Rove, Mountain, Moose, North-Fowl, South-Fowl and Superior.

Acknowledgements and thanks are due to the following persons for assistance: To M. Jules Cardot for determination of Fontinalaceæ, to Dr. R. True for determination of Dicrana, to Mr. A. J. Grout for determination and correction of the Eurhynchia, Brachythecia and Pylaisiellæ, to Mrs. E. G. Britton for determination of Orthotricha, to Dr. G. N. Best for determination and verification of Leskeæ, Thuidia, Myurellæ and Anomodonta and some other Hypnaceæ, and to Dr. C. Warnstorf for determination of the Sphagna.

A further list, including additional species, may be expected to follow this at a later date.

1. **Sphagnum acutifolium** Ehrh.
   On the point of land at the base of Kawasatchong falls, shore of Fall lake. at Camp 1 (June 8–10, 1897).
2. **Sphagnum fuscum** Klinggr.
   Near Port Arthur, Canada (June 18, 1897).
3. **Sphagnum girgensohnii** Russ.
   On the point of land at the foot of Kawasatchong falls, shore of Fall lake (June 8–10, 1897).
4. **Sphagnum medium** Limpr.
   At the farther end of the portage around Pipestone rapids, between Newton and Basswood lakes (June 11, 1897).

5. **Sphagnum recurvum parvifolium** SONDTN.
   With *Sphagnum medium.*

6. **Sphagnum teres squarrosulum** (LESQ.) WARNST.
   At the farther end of the portage around Pipestone rapids, between Newton and Basswood lakes (June 11, 1897).

7. **Sphagnum squarrosum** PERS.
   On the trail between Eve lake and fall, near the base of Kawasatchong falls (June 8–10, 1897).

8. **Sphagnum wulfianum** GIRG.
   Same locality as *S. squarrosum.*

9. **Rhabdoweisia denticulata** B. S.
   At the lower end of Pipestone rapids from Newton lake to Basswood lake (June 10, 11, 1897).
   On a small point of land at the base of the United States peninsula, shore of Basswood lake (June 11, 1897).
   On Safety island, Lake Saganaga (June 16, 1897).

10. **Cynodontium polycarpum** B. S.
    On the point of land at the base of Kawasatchong falls, shore of Fall lake, near Camp 1 (June 8–10, 1897).
    At the farther end of Pipestone rapids, shore of Basswood lake near the portage (June 10, 11, 1897).
    On the Prairie portage, shore of Basswood lake, near the rapids from Sucker lake, at Camp 4 (June 12, 13, 1897).

11. **Dicranum palustre** LA PYL (**D. boryeani** DE NOT).
    On the Prairie portage, shore of Basswood lake, near the rapids from Sucker lake, at Camp 4 (June 12, 13, 1897).
    On a small island in Lake Saganaga, called by our party Safety island, close by South island, at Camp 8 (June 16, 1897).
    On the portage from Mountain lake to Moose lake (June 20, 1897).

12. **Dicranum palustre alatum** BARNES.
    On Safety island, in Lake Saganaga. With the species (June 16, 1897).

13. **Dicranum drummondii** C. MÜLL.
    On the point of land at the base of Kawasatchong falls, shore of Fall lake, at Camp 1 (June 8–10, 1897).

At the lower end of Pipestone rapids, on Basswood Lake, near Camp 2 (June 10, 11, 1897).

On the Prairie portage, shore of Basswood lake, near the rapids from Sucker lake, at Camp 4 (June 21, 13, 1897).

On Safety island, Lake Saganaga, at Camp 8 (June 16, 1897).

On the portage from Mountain lake to Moose lake (June 20, 1897).

On Grand Portage island, north shore of Lake Superior (June 23, 1897).

14. **Dicranum flagellare** Hedw.

On the way from Ely to Winton, shore of Fall lake (June 8, 1897).

On the point of land at the base of Kawasatchong falls, shore of Fall lake, at Camp 1 (June 8–10, 1897).

At the lower end of Pipestone rapids, on Basswood lake, near Camp 2 (June 10, 11, 1897).

On Safety island, Lake Saganaga, at Camp 8 (June 16, 1897).

On the portage from North lake to South lake, the divide between the waters of Hudson Bay and Lake Superior (June 20, 1897).

On Grand Portage island, north shore of Lake Superior (June 23, 1897).

15. **Dicranum fuscescens** Turn.

At the lower end of Pipestone rapids, on Basswood lake, near Camp 2 (June 10, 11, 1897).

On the Prairie portage, shore of Basswood lake, near the rapids from Sucker lake, at Camp 4 (June 12, 13, 1897).

At the south end of Gunflint lake, at Camp 10 (June 20, 1897).

On Grand Portage island, north shore of Lake Superior (June 23, 1897).

16. **Dicranum longifolium** Hedw.

At the lower end of Pipestone rapids, on Basswood lake, near Camp 2 (June 10, 11, 1897).

On a small point of land at the base of the United States peninsula, Basswood lake (June 11, 1897).

On Basswood lake, at the farther end of the portage across the United States peninsula (June 12, 1897).

On the Prairie portage, shore of Basswood lake, near the rapids from Sucker lake, at Camp 4 (June 12, 13, 1897).

On Safety island, Lake Saganaga, at Camp 8 (June 16, 1897).

On the portage from North lake to South lake (June 20, 1897).

On the portage from Mountain lake to Moose lake (June 21, 1897).

17. **Dicranum montanum** HEDW.

On the point of land at the base of Kawastachong falls, shore of Fall lake, at Camp 1 (June 8, 9, 10, 1897).

At the lower end of Pipestone rapids, on Basswood lake, near Camp 2 (June 10, 11, 1897).

At the farther end of the portage across the United States peninsula, on Basswood lake (June 12, 1897).

On the Prairie portage, shore of Basswood lake, near the rapids from Sucker lake, at Camp 4 (June 12, 13, 1897).

On Safety island, Lake Saganaga (June 16, 1897).

At the east end of Gunflint lake (June 20, 1897).

18. **Dicranum scoparium** HEDW.

On the point of land at the base of Kawasatchong falls, on the shore of Fall lake (June 8–10, 1897).

19. **Dicranum undulatum** EHRB.

On the point of land at the base of Kawasatchong falls, shore of Fall lake (June 8–10, 1897).

On the Prairie portage, shore of Basswood lake, near the rapids from Sucker lake, at Camp 4 (June 12, 13, 1897).

On the east end of Gunflint lake, at Camp 10 (June 20, 1897).

On the portage from North lake to South lake, the divide between Hudson Bay and Lake Superior (June 20, 1897).

20. **Dicranum viride** B. S.

Along the road from Ely to Fall lake (June 8, 1897).

On the point of land at the base of Kawasatchong falls, shore of Fall lake, at Camp 1 (June 8–10, 1897).

On the Prairie portage, shore of Basswood lake, near the rapids from Sucker lake, Camp 4 (June 12, 13, 1897).

21. **Fissidens incurvus** Schw.
On the point of land at the base of Kawasatchong falls, shore of Fall lake, near Camp 1 (June 8–10, 1897).

22. **Fissidens osmundoides** Hedw.
Locality same as last.

23. **Leucobryum glaucum** Sch.
Near Camp 2, at the lower end of Pipestone rapids, on Basswood lake (June 10, 11, 1897).

24. **Ceratodon purpureus** Brid.
On the point of land at the base of Kawasatchong falls, shore of Fall lake, near Camp 1 (June 8–10, 1897).
At the farther end of the portage around Pipestone rapids, shore of Basswood lake (June 10, 11, 1897).
Along the portage from Mountain lake to Moose lake (June 20, 1897).

25. **Distichium capillaceum** B. S.
At the base of Kawasatchong falls, shore of Fall lake, Camp 1 (June 8–10, 1897).
At the base of the United States peninsula, basswood lake (June 11, 1897).
On Grand Portage island, north shore of Lake Superior (June 23, 1897).

26. **Barbula ruralis** Hedw.
At the farther end of the portage across the United States peninsula, shore of Basswood lake (June 12, 1897).

27. **Barbula tortuosa** W. and M.
On the point of land at the base of Kawasatchong falls, shore of Fall lake near Camp 1 (June 8–10, 1897).
On Grand Portage island, north shore Lake Superior (June 23, 1897).

28. **Grimmia apocarpa** Hedw.
On the Prairie portage, shore of Basswood lake, near the rapids from Sucker lake, Camp 4 (June 12, 13, 1897).

29. **Hedwigia ciliata** Ehrh.
On the point of land at the base of Kawasatchong falls, shore of Fall lake, near Camp 1 (June 8–10, 1897).

On a point of land, at the base of the United States peninsula, shore of Basswood lake (June 11, 1897).
On Safety island, Lake Saganaga (June 16, 1897).
On the portage from South-Fowl lake to Pigeon river (June 21, 1897).

30. **Amphoridium lapponicum** SCH.

On the point of land at the base of Kawasatchong falls, shore of Fall lake, near Camp 1 (June 8–10, 1897).

31. **Ulota crispa** BRID.

In the woods along the road from Ely to Winton, on Fall lake (June 8, 1897).

32. **Ulota curvifolia** BRID.

On a small point of land at the base of the United States peninsula (June 11, 1897).

33. **Ulota hutchinsiae** SCH.

On Safety island, in Lake Saganaga (June 16, 1897).

34. **Orthotrichum speciosum** NEES.

On the point of land at the base of Kawasatchong falls, shore of Fall lake, near camp 1 (June 8–10, 1897).

NOTE: This plant agrees in appearance with plants from Idaho and Washington, except that the leaves are only slightly papillose, the papillæ being mostly low and simple, exactly as figured for *O. elegans* Schwaegr., in Husnot, Musc. Gall. Another point of departure is the smooth or nearly smooth capsule. In these two points it seems to approach *O. elegans*. Yet the disposition of the cilia of the peristome is not as described in this species, but as in *O. speciosum*. The plant seems therefore to stand intermediate between *O. speciosum* and *O. elegans*. And in that case Schwägrichen's species is rather *Orthotrichum speciosum elegans*.

35. **Orthotrichum speciosum roellii** VENT.

On trees along the road from Ely to Winton, Fall lake. (June 8, 1897).

36. **Encalypta ciliata** HEDW.

On the point of land at the base of Kawasatchong falls, shore of Fall lake, near Camp 1 (June 8–10, 1897).

37. **Teraphis pellucida** HEDW.

On the point of land at the base of Kawasatchong falls, shore of Fall lake, near Camp 1 (June 8–10, 1897).

On a small point of land at the base of United States peinsula, shore of Basswood lake (June 11, 1897).

At the lower end of the portage around Pipestone rapids, shore of Basswood lake (June 10, 11, 1897).

On Safety island, Lake Saganaga (June 16, 1897).

On the portage from South lake to Rat lake (June 20, 1897).

38. **Funaria hygrometrica** HEDW.

On the portage from North lake to South lake, the divide between Hudson Bay and Lake Superior (June 20, 1897).

39. **Bartramia oederi** SCHW.

Along the road from Ely to Winton, shore of Fall lake (June 8, 1897).

On the point of land at the base of Kawasatchong falls, shore of Fall lake, near Camp 1 (June 8–10, 1897).

40. **Bartramia pomiformis** HEDW.

On the lower end of the portage around Pipestone rapids, shore of Basswood lake, near Camp 2 (June 10, 11, 1897).

On a small point of land, at the base of the United States peninsula, Basswood lake (June 11, 1897).

On the Prairie portage, shore of Basswood lake, near the rapids from Sucker lake (June 12, 13, 1897).

On Safety island, Lake Saganaga (June 16, 1897).

Near Gunflint station (June, 1897).

On the portage from Mountain lake to Moose lake (June 21, 1897).

On Grand Portage island, north shore of Lake Superior (June 23, 1897).

41. **Leptobryum pyriforme** SCH.

On the point of land at the base of Kawasatchong falls, shore of Fall lake, near Camp 1 (June 8–10, 1897).

42. **Webera nutans** HEDW.

Same station as the last.

43. **Mnium cuspidatum** HEDW.
Same station as the last.

44. **Mnium punctatum** HEDW.
On the road from Ely to Fall lake (June 8, 1897).
At Camp 1, Fall lake (June 8–10, 1897).

45. **Mnium serratum** BRID.
On a small point of land at the base of the United States peninsula, shore of Basswood lake (June 11, 1897).
On Safety island, Lake Saganaga (June 16, 1897).

46. **Timmia bavarica** HESSL. var **cucullata** (MICHX.).
On Grand Portage island, north shore of Lake Superior (June 23, 1897).

47. **Atrichum undulatum** P. B.
On the point of land at the base of Kawasatchong falls, shore of Fall lake, near Camp 1 (June 8–10, 1897).

48. **Pogonatum alpinum** ROELL.
On Grand Portage island, north shore of Lake Superior (June 23, 1897).

49. **Polytrichum commune** L.
Same station as the last.

50. **Polytrichum juniperinum** WILLD.
On the point of land at the base of Kawasatchong lake, shore of Fall lake, near Camp 1 (June 8–10, 1897).

51. **Polytrichum piliferum** SCHREB.
On the prairie portage, shore of Basswood lake, near the rapids from Sucker lake (June 12, 13, 1897).

52. **Fontinalis antipyretica** LINN.
In the river crossing the Grand portage about four miles north of Grand Portage village. Abundant (June 21, 1897).

53. **Fontinalis duriaei** SCH.
On submerged rocks at the base of Kawasatchong falls near Camp 1 (June 8–10, 1897).

54. **Fontinalis holzingeri** CARDOT. sp. nova in litt.
At the second falls of Granite river ascending from Lake Saganaga (June 17, 1897).
"Du groupe Heterophyllæ, voisine du *F. missourica* Card., sed foliis rigidioribus, reti firmo, cellulis longi-

oribus, haud vel vix flexuosis, valde chlorophyllosis, parietibus firmis, distincta."

55. **Fontinalis hypnoides** HARTM. "forma foliis apice saepe denticulata."

In the stream flowing from North lake into Little Gunflint lake. Abundant at the lower end of the stream (June 20, 1897).

56. **Dichelyma pallescens** B. S.

At the base of alder trunks growing along the bank of Fall lake, near Camp 1 (June 8–10, 1897).

57. **Neckera oligocarpa** B. S.

Near Camp 1 at the base of Kawasatchong falls, shore of Fall lake (June 8–10, 1897).

On a small point of land near the base of the United States peninsula, Basswood lake (June 11, 1897).

At the farther end of the portage across the United States peninsula, Basswood lake (June 12, 1897).

On Safety island, Lake Saganaga (June 16, 1897).

On Grand Portage island, north shore of Lake Superior (June 23, 1897).

58. **Neckera pennata** HEDW.

On trees along the road from Ely to Winton, on Fall lake (June 8, 1897).

Near Camp 1, on Fall lake (June 10–12, 1897).

On the Prairie Portage, shore of Basswood lake, near the rapids from Sucker lake (June 12, 13, 1897).

59. **Homalia trichomanoides jamesii** (SCHIMP.).

Near Camp 1, at the base of Kawasatchong falls, shore of Fall lake (June 8–10, 1897).

On the portage from Fall lake to Newton lake (June 10, 11, 1897).

On a small point of land at the base of the United States peninsula, Basswood lake (June 11, 1897).

NOTE: This plant has leaves varying strongly toward the typical European form of the species.

On Grand Portage island, north shore of Lake Superior (June 23, 1897).

NOTE: I have carefully studied the plants collected; have compared them with Professor Macoun's Canadian specimens sent out under No. 242; also with the *Ho-*

malia collected by Professor James, near Franconia, N. H., named *H. jamesii* Schimp., and probably typical material of Schimper's species, also with *H. trichomanoides* from Denmark, collected by Dr. J. Hensen, near Hvalsö, in 1883; and I fail to find a single good reason for separating our American forms of *Homalia* with serrate leaves from the European *Homalia trichomanoides* as a distinct species. Not a single constant character can be established for our plant. I have made micrometer measurements of the leaf cells of all the specimens examined, and I find them essentially of the same size in the same part of the leaf in all specimens. The American specimens that are fertile show not the slightest difference from European specimens either in perichætial leaves or in perforation of the segments of the peristome along the keel. The only point of difference is the, on the whole, more obtuse apex of the leaves in our American forms. But it cannot fail to attract the attention of the student, especially when he reviews a large number of forms in different collections, that while in our American forms the apex is on the whole more rounded, some leaves may be found on every plant which have an apiculate apex. Also the European plants studied show some leaves more rounded at the apex than others. As for the description of the European plant, by European authors themselves, let me cite first from Muscineés de la France by M. l'Abbé Boulay (1884), p. 150. "Féuilles largement oblongue-elliptiques, convexes-cultriformes par le bord superieur, un peu repliées en dessus par l'inflexion du bord inferieur, brevement apiculées, très finement denticulées sur tout le contour (dont plus grandes et plus rapprochées ver le sommet; long. 2, larg. 1 mm. * * * * * cellules moyennes 8–10 fois aussi l. q. l.; vers les bords et au sommet, elles sont courtes, rhomboidales; * * * * * lanieres du peristome interne linéares, plus longues que les dents, peu ou millement ouvertes ver la carene."

In Limpricht's Laubmoose II (1895), p. 715: "Blätter gedrängt, zweizerlig-abstrehend, zuletst abwärts gebogen, flach ausgebreiten, unsymmetrisch, aus herablaufender, etwas verschmälerter Bariszungen-messerförmung, stümpflich, 1.8–2 mm. lang, und 1 mm. breit, am Rande der oberen Blatt hälfte ausgefressen-gezähnt, am Grunde, an einer Seite eingeschlagen * * * Innerer Peristom * * * in der linie ritzenförmig durch brochen."

Now in Macoun's Cat. of Can. Pl., 4 (1892), p. 163, the authors of *Homalia macounii*, say of it: "Very nearly allied to *Homalia trichomanoides;* differs in the leaves being longer, rather lingulate, the lowest basal cells yellow, the perichætial leaves more suddenly narrowed to a very short acumen, the segments of the peristome cleft between the articulations." This is quite all in the line of characterization. Among other localities it is credited to Lake Superior, Drummond's specimens having been collected there.

Both from actual comparison and from the circumstance of locality, the Lake Superior plants collected by me are reasonably referred to the same plants upon which *Homalia macounii* is founded. If this inference is correct then the only valid part of the above statements, which stand in place of description, is the first phrase "very nearly allied to *H. trichomanoides*." The leaf length varies according to European authors themselves. The "rather lingulate" form of outline is ascribed by Limpricht to *Homalia trichomanoides*, when he makes the leaves "zungen-messerförmung," *i. e.*, "lingulate-cultriform." As to the "lowest basal cells yellow, the perichætial leaves more suddenly narrowed to a very short acumen," my own close observations fail to verify these two characters, which, if observed by the authors, must have been purely accidental. And as for "the segments of the peristome cleft between the articulations," this character, judging both the European specimens actually examined, and from the painstaking description of *Homalia trichomanoides* made by European authors themselves, as seen from citations above, is unconditionally conceded to belong to *Homalia trichomanoides* Br. The only tangible difference, the slightly more obtuse leaves it certainly has in common with Dr. James' own specimens of *Homalia jamesii*. If now we turn to Lesq. and James' Manual of Mosses of North America (1884), p. 285, we find not a single positive or new character assigned to *Homalia jamesii*, except leaves "striolate lengthwise when dry." And this point is not borne out by the actual examination of James' own material.

It appears, therefore, that *Homalia jamesii* is too close to *H. trichomanoides;* that *Homalia macounii* is identical with *Homalia jamesii*; that the only difference is found in the more obtuse leaves of our species, which proves to be a variable character, and therefore that it should not stand as a distinct species, hardly deserving the name of a variety. As a variety it must be called:

Homalia trichomanoides jamesii (SCHIMP.).

H. jamesii Schimp. in Syn. (   ), p. 473.
H. macounii in Mac. Cat. (1892), p. 163.

The geographical distribution of this variety of *Homalia trichomanoides*, includes necessarily all the stations cited in Macoun's Catalogue for *H. macounii* with those given for *H. jamesii* in Lesquereux and James' Manual.

60. **Myurella careyana** SULL.

On Grand Portage island, north shore of Lake Superior (June 23, 1897).

61. **Myurella julacea** SCH.

At the base of Kawasatchong falls, shore of Fall lake, near Camp 1 (June 8–10, 1897).

On Grand Portage island, north shore of Lake Superior (June 23, 1897).

62. **Leskea nervosa** MYR.

On the Prairie portage, shore of Basswood lake, near the rapids from Sucker lake (June 12, 13, 1897).

63. **Leskea polycarpa** EHRH.

At the farther end of the portage across the United States peninsula, shore of Basswood lake (June 12, 1897).

On the Prairie portage, shore of Basswood lake, near the rapids from Sucker lake (June 12, 13, 1897).

64. **Leskea polycarpa paludosa** SCH.

On the way from Ely to Winton, shore of Fall lake (June 8, 1897).

Along the shore of Fall lake, near Camp 1 (June 8–10, 1897), abundant.

65. **Anomodon attenuatus** Hartm.

Shore of Fall lake, near Camp 1 (June 8–10, 1897).

On a small point of land, at the base of the United States peninsula, shore of Basswood lake (June 11, 1897).

On the Prairie portage, shore of Basswood lake, near the rapids from Sucker lake (June 12, 13, 1897).

66. **Anomodon minor** (P. Beauv.) Fürn.

On the shore of Fall lake, base of Kawasatchong falls, near Camp 1 (June 8–10, 1897).

67. **Anomodon rostratus** Sch.

On the shore of Fall lake, base of Kawasatchong falls, near Camp 1 (June 8–10, 1897).

On a small point of land, at the base of the United States peninsula, shore of Basswood lake (June 11, 1897).

On the Prairie portage, shore of Basswood lake, near the rapids from Sucker lake (June 12, 13, 1897).

68. **Pylaisia heteromalla** Sch.

On trees along the shore of Fall lake, near Camp 1 (June 8–10, 1897).

On a small point, at the base of the United States peninsula, Basswood lake (June 11, 1897).

69. **Pylaisia polyantha** Sch.

On trees along the shore of Fall lake, near Camp 1 (June 8–10, 1897).

On the Prairie portage, shore of Basswood lake, near the rapids from Sucker lake (June 12, 13, 1897).

70. **Platygyrium repens** Sch.

Shore of Fall lake, near Camp 1. On dead logs (June 8–10, 1897).

71. **Cylindrothecium seductrix** Sulliv.

Same locality as above.

72. **Climacium americanum** Brid.

Same locality as above.

Portage from Mountain lake to Moose lake (June 20, 1897).

73. **Thuidium abietinum** SCH.
Shore of Fall lake, near Camp 1 (June 8–10, 1897).
On the Prairie portage, shore of Basswood lake (June 12, 13, 1897).
On the portage from South-Fowl lake to Pigeon river (June 21, 1897).
On Grand Portage island, north shore of Lake Superior (June 23, 1894).

74. **Thuidium recognitum** LINDB.
Shore of Fall lake, near Camp 1 (June 8–10, 1897).

75. **Thuidium philiberti** LIMPR.
At camp, shore of Fall lake (June 8–10, 1897).

76. **Brachythecium campestre** SCH.
Shore of Fall lake near Camp 1 (June 8–10, 1897).

77. **Brachythecium flexicaule** REN. and CARD.
On the Prairie portage, shore of Basswood lake (June 12, 13, 1897).

78. **Brachythecium oxycladon** (BRID.). Grout.
At the base of the United States peninsula, shore of Basswood lake (June 11, 1897).
On the Prairie portage, shore of Basswood lake (June 12, 13, 1897).
On Grand Portage island, north shore of Lake Superior (June 23, 1897).
This last is pronounced a "slender form" by Mr. Grout.

79. **Brachythecium plumosum** SCH.?
On the Prairie portage, shore of Basswood lake (June 12, 13, 1897).

80. **Brachythecium salebrosum** SCH.
Shore of Fall lake, near Camp 1 (June 8–10, 1897).

81. **Brachythecium starkei** SCH.
At the base of the United States peninsula, shore of Basswood lake (June 11, 1897).

82. **Eurynchium robustum** (ROELL.).
At the base of the United States peninsula, shore of Basswood lake (June 11, 1897).
On Basswood lake, at the farther end of the portage across the United States peninsula (June 12, 1897).

Mr. Grout remarks that these plants vary toward *E. strigosum*; they are probably only large forms of this species.

83. **Eurynchium strigosum** Sch.
Shore of Fall lake, near Camp 1 (June 8–10, 1897).
On the portage from South lake to Rat lake (June 20, 1897).
On the portage from South-Fowl lake to Pigeon river (June 21, 1897).
On Grand Portage island, north shore of Lake Superior June 23, 1897).

84. **Raphidostegium recurvans** L. and J.
Shore of Fall lake, near Camp 1 (June 8–10, 1897).
On the point of land at the base of the United States peninsula, Basswood lake (June 11, 1897).
On Safety island, Lake Saganaga (June 16, 1897).

85. **Plagiothecium denticulatum** Sch.
On the road from Ely to Winton, shore of Fall lake (June 8, 1897).
At Camp 1, shore of Fall lake, near Kawasatchong falls (June 8–10, 1897).

86. **Plagiothecium muhlenbeckii** Sch.
At Camp 1, shore of Fall lake (June 8–10, 1897).

87. **Plagiothecium sylvaticum** Sch.
At Camp 1, shore of Fall lake (June 8–10, 1897).
On Grand Portage island, north shore of Lake Superior (June 23, 1897).

88. **Amblystegium adnatum** L. and J.
At Camp 1, shore of Fall lake (June 8–10, 1897). Det. by *G. N. Best.*

89. **Amblystegium serpens** Sch.
On the portage from Mountain lake to Moose lake (June 20, 1897).

90. **Hypnum chrysophyllum** Brid.
At Camp 1, shore of Fall lake (June 8–10, 1897).

91. **Hypnum cupressiforme ericetorum** B. S.
At Camp 1, shore of Fall lake (June 8–10, 1897).
At the lower end of Pipestone rapids, on Basswood lake (June 10, 11, 1897).

92. **Hypnum crista-castrensis** L.

On the road from Ely to Winton, on Fall lake (June 8, 1897).

At Camp 1, on Fall lake (June 8–10, 1897).

At the lower end of Pipestone rapids, on Basswood lake (June 10, 11, 1897).

At the base of the United States peninsula, Basswood lake (June 11, 1897).

Near Camp 3, at the farther end of the portage across the United States peninsula, on Basswood lake (June 12, 1897).

On Prairie portage, shore of Basswood lake (June 12, 13, 1897).

On Safety island, Lake Saganaga (June 16, 1897).

93. **Hypnum filicinum trichodes** Brid.

On Grand Portage island, north shore of Lake Superior (June 23, 1897).

Dr. Best remarks that this approaches the variety *aciculinum* C. M. and K.

94. **Hypnum haldanianum** Grev.

On the road from Ely to Fall lake (June 8, 1897).

At Camp 1, on Fall lake, near Kawasatchong falls (June 8–10, 1897).

At the lower end of the Pipestone rapids, on Basswood lake (June 10, 11, 1897).

At the base of the United States peninsula, on Basswood lake (June 11, 1897).

On the portage from South lake to Rat lake (June 20, 1897).

95. **Hypnum hispidulum** Brid.

On the road from Ely to Fall lake (June 8, 1897).

At Camp 1, on Fall lake (June 8–10, 1897).

96. **Hypnum reptile** Rich.

At Camp 1, on Fall lake (June 8–10, 1897.)

At a small point of land at the base of the United States peninsula, Basswood lake (June 11, 1897).

97. **Hypnum schreberi** Willd.

At Camp 1, on Fall lake (June 8–10, 1897).

At the lower end of the Pipestone rapids, on Basswood lake, near Camp 2 (June 10, 11, 1897).

At the base of the United States peninsula, Basswood lake (June 11, 1897).
At the farther end of the portage across the United States peninsula, Basswood lake (June 12, 1897).
On Safety island, Lake Saganaga (June 16, 1897).
At the east end of Gunflint lake (June 20, 1897).
On Grand Portage island, north shore of Lake Superior (June 23, 1897).

98. **Hypnum uncinatum** HEDW.
On the road from Ely to Fall lake (June 8, 1897).
On the portage across the divide (June 20, 1897).

99. **Holocomium splendens** SCH.
At Camp 1, shore of Fall lake (June 8–10, 1897).
At the base of the United States peninsula, Basswood lake (June 11, 1897).
On the Prairie portage, shore of Basswood lake (June 12, 13, 1897).
On Safety island, Lake Saganaga (June 16, 1897).
At the east end of Gunflint lake (June 10, 1897).
On Grand Portage island, north shore of Lake Superior (June 23, 1897).

100. **Hylocomium triquetrum** SCH.
On the road from Ely to Fall lake (June 8, 1897).
At Camp 1, shore of Fall lake (June 8–10, 1897).
At the farther end of the portage across the United States peninsula, shore of Basswood lake (June 12, 1897).
On Safety island, Lake Saganaga (June 16, 1897).
At the east end of Gunflint lake (June 20, 1897).
On Grand Portage island, north shore of Lake Superior (June 23, 1897).

VII. THE INFLUENCE OF GASES AND VAPORS UPON THE GROWTH OF PLANTS.

EMIL P. SANDSTEN.

INTRODUCTION.

In recent years considerable attention has been paid by physiologists to the influence of various chemical agents upon the growth of plants, and the results thus far obtained seemed to warrant further investigation along this line. The work heretofore has been confined almost exclusively to the lower plant forms, which are more easily attacked by the difficult technique which is bound up in this kind of inquiries. The recent preliminary results of Johanssen (1) were announced shortly after this work was begun, and it was thought advisable to extend the work to cover the phases of the vegetative period as well as resting seeds, etc. To some extent the writer has had in mind the ultimate application of the reactions obtained in practical gardening though such results are reserved for verification and further trial. The work was done during the fall and winter of 1897 and 1898 in the laboratories of plant physiology in the University of Minnesota under the direction of Dr. D. T. Mac Dougal, to whom the writer is greatly indebted for his valuable advice and kind criticism.

MATERIAL AND METHODS.

The experiments may be conveniently classified as follows:

1. The influence of gases and vapors upon seeds.
2. The influence of gases and vapors upon seedlings.
3. The influence of gases and vapors upon growing shoots.
4. The influence of gases and vapors upon resting bulbs, corms, etc.
5. The influence of gases and vapors upon plants growing in water cultures.

The reagents used were alcohol, ammonia, carbon bisulphide, chloroform, ether, nitrous oxide and oxygen. Small quantities of alcohol (methyl), ammonia (hydrate), carbon bisulphide, ether and chloroform were placed in tubes inside of closed receivers and allowed to vaporize into the air enclosed. The nitrous oxide was the commercial mixture, N_2O 90 parts, N 8.86, O 1.13. In certain experiments the pure gas which had been obtained from ammonium nitrate was used. Commercial oxygen from tanks was used.

As a means of control and test of the actual efficiency of the reagents, leaves of *Philotria* (*Elodea*) and hairs of *Tradescantia*, Tomato, *Begonia*, *Pelargonium* and *Geranium* were mounted in an Engelmann gas chamber and subjected to their action. These tests were carried on at a room temperature of 16 to 23° C., and the results noted below are quite in harmony with those given by previous writers.

Oxygen. The movements of protoplasm are greatly accelerated in an atmosphere of free oxygen for five to seven minutes, after which the movements gradually diminish until they cease entirely. If the living cell is kept under the influence of free oxygen for considerable length of time it dies, but no apparent change in the structure or behavior of the protoplasm could be noticed.

Nitrous oxide (N_2O). This gas has the same general effect on living protoplasm as oxygen with the exception that it is less and does not kill the cell even when exposed for several days in an atmosphere of 90 per cent. nitrous oxide. The duration of active movements varies from three to five minutes (Moeller V.).

Chloroform and Ether. The action of these two reagents are about the same. Aqueous solutions containing 1/20000 part of reagents at first slightly increase the movements of the protoplasm. By increasing the strength of the solution the rapidity of movement was also increased, but the reaction time was very much shortened. Strong solution causes vacuolization and paralyzes the protoplasm.

Ammonia. Weak aqueous solution containing from 1/30000 to 1/20000 parts of ammonia does not seem to modify the activity of the protoplasm when subjected to its action for a short time only. Stronger solution produces vacuolization and slightly accelerates the movements of the protoplasm for a minute or two.

Carbon bisulphide.—The smallest possible quantity that could be introduced arrested all movements.

Alcohol.—Aqueous solutions containing 1/20000 to 1/10000 parts of alcohol had no visible effect upon the protoplasm. A

2 per cent. solution excited rapid irregular movements which stopped inside of two minutes. Vacuolization followed rapidly and the cell was killed inside of ten minutes.

In the experiments where seeds and seedlings were used, *Zea mais*, *Vicia* and *Phaseolus* were employed exclusively. Strawberry plants of the common cultivated kind were used in the experiments with growing shoot and proved well adapted to the work. The strawberry plants were taken from the bed on November 6, 1897, and carefully selected with reference to vigor and equality. Two lots of plants were selected, one lot composed of plants one season old, the other composed of plants two seasons old. The plants were placed in three- and four-inch pots respectively November 9th, and set in a cold frame where they remained until December 9th, when they were taken to the green house and put under the experimental conditions described below.

Dormant bulbs and corms of *Arisæma*, *Narcissus*, Hyacinth, Tulip, *Freesia* and *Crocus* were used for material in the resting stage.

In the experiments with gases in nutrient solution in water culture seedlings of *Zea mais* were used. A large number of seeds were germinated in clean saw-dust and when the seedlings had attained the desired growth the specimens which were to be used in the experiment were carefully selected for vigor and equality. The vessels holding the nutrient solution were glazed earthen jars of two litres capacity. The tops of the earthen jars were fitted with covers made of plaster of paris. Through each cover two holes were drilled, one for the seedlings and a second to admit the necks of inverted flasks of gas. The seedlings were fastened in the openings in the covers by means of a perforated cork after the usual manner in water cultures. The flasks were filled with water, inverted with the necks immersed in the culture fluid and filled with gas by displacement through a bent glass delivery tube.

The following formula was used in making up the nutrient solutions:

Potassium nitrate	25.	gm.
Sodium chloride	12.5	"
Calcium sulphate	12.5	"
Magnesium sulphate	12.5	"
Calcium phosphate	12.5	"
Water	250.	cc.

The solution was diluted to 12500 cc. and from five to eight drops of ferric chloride were introduced in each jar before using.

The bell jars used in enclosing the bulbs and shoots had ground edges and were set upon ground glass plates which had been anointed with a preparation composed of vaseline, tallow and resin, to make the connection absolutely air tight. The temperature was kept as constant as possible.

The pressure of one atmosphere is to be understood where not otherwise stated.

1. THE INFLUENCE OF GASES AND VAPORS UPON THE GERMINATION OF SEEDS.

A. *Gases.* The gases used were nitrous oxide and oxygen. Seeds of *Phaseolus multiflorus* and *Vicia faba* were soaked in water for twenty-four hours and from these were selected ten normal specimens for each experiment. They were then placed on sections of cork, which had previously been soaked in water and introduced into the bell jar under water so as to prevent any air from gaining admittance. Duplicate experiments and duplicate controls were set up. The capacity of bell jars was two litres.

The results obtained with nitrous oxide and oxygen agree with previous experiments in the same line. (Detmer II.) The seed germinated readily in an atmosphere of free oxygen, but failed to do so in an atmosphere of nitrous oxide. The nitrous oxide gas did not kill the seeds, as they afterwards germinated under a bell jar in ordinary air. The N_2O used here was obtained from ammonium nitrate.

B. *Vapors.* Seeds of *Phaseolus multiflorus* and *Vicia faba* were placed under bell jars, 4000 cc. capacity, tightly secured to glass plates. Twelve dry seeds of each kind were placed under each bell jar, together with a small glass vial containing accurately measured quantities of the reagent. The seeds were kept under the bell jars for nine days, when they were taken out and each lot planted separately in four-inch pots. The control experiment was treated exactly in the same way as the others with the exception of the omission of the chemicals. The plants were growing side by side and received the same treatment.

TABLE I.

(KEY.)

I. 1/32000 parts of NOH_4
II. 1/28000 " " "
III. 1/24000 " " "
IV. 1/20000 " " "
(a) *Phaseolus multiflorus.*
(b) *Vicia faba.*
(c) Control of *Phaseolus.*
(d) Control of *Vicia.*

		Per cent. of germination.	Average height 10 days after planting.	Average height 28 days after planting.	Time of blooming.
I.	(a)	100	19 mm.	28 cm.	30 days.
	(b)	90	33 mm.	12.5 cm.	—
	(c)	100	+(a) 51 mm.	30.5 cm.	33 days.
	(d)	100	+(b) 59 mm.	15 cm.	—
II.	(a)	100	18.5 mm.	22.5 cm.	29 days.
	(b)	2	25 mm.	*11.5 cm.	—
	(c)	100	+(a) 51 mm.	30.5 cm.	33 days.
	(d)	100	+(b) 59 mm.	15 cm.	—
III.	(a)	80	30 mm.	27 cm.	31 days.
	(b)	20	51 mm.	11.5 cm.	—
	(c)	100	+(a) 51 mm.	30.5 cm.	33 days.
	(d)	100	+(b) 59 mm.	15 cm.	—
IV.	(a)	0	0	0	—
	(b)	0	0	0	—
	(c)	100	+(a) 51 m.	30.5 cm.	33 days.
	(d)	100	+(b) 59 m.	15 cm.	—

It will be seen that very small quantities of ammonia vapors are not fatal to the germination. In none of the experiments had any of the seeds germinated during the nine days they were under the bell jars, nor had any of the seeds in the control germinated. The odor of ammonia from the seeds treated could readily be detected. It was noticed throughout the experiments that the plants from the treated seeds had a deeper green color than the control. This was especially noticeable in the case of *a* and *b* in series I and II. Nor did it appear that the ammonia vapor had any subsequent bad effect on the plants; on the contrary in series I and II it seems to have hastened the time of the flowering by three to four days. *Vicia faba* is more susceptible to ammonia vapors than *Phaseolus multiflorus*. As in the case of *Phaseolus multiflorus* the leaves were darker than in the control. The measurements given in the table above represent the average growth of shoot of twelve plants.

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* One plant only.

2. THE INFLUENCE OF GASES AND VAPORS UPON SEEDLINGS.

A. *Gases*.—Nitrous oxide of oxygen and seedling of *Zea mais* and *Phaseolus multiflorus* were employed in these experiments. The seedlings were carefully measured and placed under bell jars while full of water which was displaced by the gases.

The following quantities of gases were used: 400 cc. of nitrous oxide in 2000 cc. of air and an atmosphere of free nitrous oxide; 400 cc. of oxygen in 2000 cc. of air and an atmosphere of free oxygen. These were set up in duplicates and the control was also in duplicate. The results of the experiments showed an increase in growth for seedlings in the two oxygen experiments and also for the nitrous oxide experiment in which 400 cc. in 2000 cc. of air was used. The average increase in the two oxygen experiments and the control for 24 hours was little less than 8 mm. The seedlings in the atmosphere of free oxygen did not average as much as those in the partial atmosphere of oxygen. The average was 5 mm.

The seedlings in the experiments in which 400 cc. in 2000 cc. of air was used showed a slight increase in growth over the control, amounting on an average to 3 mm. The seedlings in an atmosphere of free nitrous oxide did not make any growth, but were alive when taken from the bell jar. The temperature during the time the experiments were running varied from 21–23° C.

B. *Vapors*.—The following chemicals were used: Ether, chloroform, carbon bisulphide, alcohol and ammonia. Seeds of *Zea mais* were germinated in clean saw-dust and when the roots had attained a length of 15 to 20 mm. and the plumule from 10 to 15 mm. a uniform lot was selected for the experiments. The roots and shoots were carefully measured and marked with India ink. The seedlings were next placed under the bell jars of 2000 cc. capacity upon moist saw-dust. The chemicals were accurately measured out and put into small glass bottles containing 100 cc. of water and then placed under the bell jars with the seedlings. The temperature during the experiments varied from 21–23° C. A new quantity of chemical was introduced each time after the seedlings were measured, thus keeping the amount of vapors constant throughout the time the experiments were running. Commercial mixtures of nitrous oxide were used in the above series.

The results are given below in Tables II and III.

TABLE II.

I. .2 cc. of ether in 2000 cc. of air.
II. .2 cc. of chloroform in 2000 cc. of air.
III. .2 cc. of carbon bisulphide in 2000 cc. of air.
IV. .5 cc. alcohol in 2000 cc. of air.
V. Control.

a. Plumule.
b. Root.

Series.	Plants.	Average growth of plumule and root of 10 seedlings in 3 hours.	Average growth of plumule and root of 10 seedlings in 5 hours.	Average growth of plumule and root of 10 seedlings in 24 hours.	Average growth of plumule and root of 10 seedlings in 48 hours.	Total gain or loss over the control.
I.	a.	1.4 mm.	2.15 mm.	9.75 mm.	28.25 mm.	+ 2.45 mm.
	b.	1.75 mm.	3.5 mm.	26 mm.	39.5 mm.	+ 7.5 mm.
II.	a.	1.25 mm.	2.25 mm.	20.3 mm.	32.66 mm.	+ 6.66 mm.
	b.	1.4 mm.	2.5 mm.	28.66 mm.	37.66 mm.	+ 5.66 mm.
III.	a.	1.4 mm.	2.4 mm.	7.25 mm.	14.25 mm.	— 10.55 mm.
	b.	1. mm.	2.88 mm.	6.5 mm.	9. mm.	— 28. mm.
IV.	a.	1.5 mm.	2.75 mm.	14.25 mm.	28.5 mm.	
	b.	2. mm.	2.5 mm.	8.5 mm.	18.25 mm.	— 13.75 mm.
V.	a.	1.2 mm.	2.1 mm.	11.8 mm.	25.8 mm.	......
	b.	1.45 mm.	2.5 mm.	16.5 mm.	32. mm.	......

Table III.

I. .4 cc. of ether in 2000 cc. of air.
II. .4 cc. of chloroform in 2000 cc. of air
III. .4 cc. of carbon bisulphide in 2000 cc. ot air.
IV. 1. cc. of alcohol in 2000 cc. of air.
V. .2 cc. of ammonia in 2000 cc. of air.
VI. Control.

Series.	Roots.	Average growth of roots of 10 seedlings for 6 hours.	Average growth of roots of 10 seedlings for 24 hours.	Total loss or gain over the control.
I.		1.3 mm.	10. mm.	— 3.1 mm.
II.		1. mm.	7.5 mm.	— 5.6 mm.
III.		.6 mm.	.6 mm.	— 12.5 mm.
IV.		dead.	dead.	
V.		1.3 mm.	13.2 mm.	+ .1 mm.
VI.		1.17 mm.	13.1 mm.	......

From the above tables it will be seen that a very small amount of carbon bisulphide or ammonia vapors is very injurious to young seedlings, while ether, chloroform and alcohol vapors in minute quantities are not injurious when the plant is not subjected to their prolonged action. On the contrary, small amounts of ether and chloroform vapors seem to accelerate growth.

3. THE INFLUENCE OF GASES AND VAPORS UPON GROWING SHOOTS.

A. *Gases.*—Nitrous oxide and oxygen were used in these experiments in the following quantities: 25 per cent., 50 per cent. and 100 per cent. The plants were kept under the bell jars for twenty days.

TABLE IV.

I. 25 per cent. of gas in 4000 cc. of air.
II. 50 per cent. of gas in 4000 cc. of air.
III. One atmosphere of free gas.
IV. Control.

a. Nitrous oxide.
b. Oxygen.

Series.	Chemicals.	Time of first flowers.	Number of flowers.	Number of leaves.	Scale of vigor. Control taken as standard.
I.	a.	43 days.	3	8	112
	b.	64 days.	3	7	103
II.	a.	28 days.	17	14	125
	b.	no flowers.	no flowers.	3	45
III.	a.	42 days.	3	7	102
	b.	dead.	....	....	
IV.	a.	44 days.	1	6	100
	b.	46 days.	3	7	100

In the above table the plants treated with nitrous oxide show a marked increase in vigor and flowering capacity. The leaves were of a dark green color and very large. The leaf petioles were somewhat shortened, giving the plants a stocky appearance. The root systems of the plants treated with nitrous oxide were very strong. All evidence seems to point to the conclusion that the treatment was beneficial to the plants. The oxygen also appeared to be beneficial to the plants when used in quantities not exceeding 50 per cent. In an atmosphere of free oxygen the plants showed no deviation from the normal while in the gas, but upon the removal of the bell jar the plants soon began to show signs of decay. The plants treated with oxygen exhibited a marked elongation of the petioles.

B. *Vapors.*—Ammonia and chloroform were used in these experiments in the following quantities: 1 10000, 1 15000 and 1 40000 parts. The capacity of the bell jars was 7500 cc. The reagents were introduced in an aqueous solution of 100 cc. The plants were kept under the bell jars for 26 hours. Upon examination it was found that the plants which had been subjected to the influence of 1 10000 part of ammonia or chloroform vapors were dead. The leaves had assumed a dirty brown color. The center of the shoot was badly discolored. The appearance of the plants was very similar to that of a frozen plant. The plants which were subjected to 1/15000 part of the reagents were badly effected, the outer leaves were dark brown but the center was not affected. The plants grew but remained weak and straggling throughout the time the experiments were running. The action of the two reagents seemed to be the same, little or no difference could be detected.

The plants which were kept in an atmosphere containing 1/40000 part of the reagents did not appear to be visibly affected when taken from the bell jars. The subsequent influence of the reagents was, however, very marked, especially on the plants in the chloroform experiment. Compared with the control plants at the end of the experiment, February 10, with which they were equal at the start, they showed a great advance.

4. The Influences of Gases and Vapors upon Resting Bulbs.

The bulbs used in these experiments were *Arisæma triphyllum*, *Narcissus*, Hyacinth, *Crocus*, and *Freesia*. The reagents used were oxygen, nitrous oxide, ether, chloroform, carbon bisulphide, ammonia and alcohol. These experiments were started in November and December, months in which bulbs of this kind are very hard to start, since they require a certain period of rest before beginning growth and this period generally extends through the months of October, November and December.

The bulbs were kept under bell jars and the reagents which were in a liquid form were introduced in aqueous solution. Where gases were used in the experiments they were introduced by displacement.

A. *Gases.—Narcissus* bulbs were placed under bell jars containing oxygen in the following proportion: 20 per cent., 50 per cent. and 100 per cent. The capacity of the bell jars was 4000 cc.

TABLE V.

I. 20 per cent. of gas.
II. 50 per cent. of gas.
III. 100 per cent. of gas.
IV. Control.

a. Nitrous oxide.
b. Oxygen.

Exposed to gas ten days.

Series.	Reagent.	Average growth when taken from bell jars. mm.	Average growth in 20 days. mm.	Average growth in 30 days. mm.	Average growth in 40 days. mm.	Average growth in 60 days. mm.	Time of first flower. days.	Number of flowers.	Number of flowers from each bulb.
I.	a.	18	70	180.5	260.5	590	44	2	2
	b.	10	60	210.5	330	620	44	4	2
II.	a.	7.5	75	210.5	320.	609	48	1	1
	b.	0	30	230.	440	630	0	0	0
III.	a.	7	50	210.5	330.5	625	38	3	1.5
	b.	0	25	209.5	315	615	44	4	2
IV.	control	29	85	250.5	370.5	640	42	2	2
		18	65	150	280	580	43	3	1.5

It is to be regretted that the root system could not be measured and examined during the experiments without injuring the plants to such an extent as to make the experiment useless. The table does not show anything in favor of the plants treated. The only conclusion that can be drawn is that these gases have no perceptible influence on *Narcissus* bulbs.

Ammonia.—Vapors of this reagent are not injurious to the resting bulb when the amount of vapor present does not exceed one part in 5000 of air. *Arisæma triphyllum*, *Narcissus*, *Crocus*, *Freesia* and Tulip bulbs were exposed to an atmosphere containing one part of ammonia in 5000 of air for ten days without injuring the growing qualities of the bulb.

Chloroform.—Vapors of chloroform seem to be very injurious to resting bulbs. The following quantities of the reagent were used: 1/1000, 1/5000 and 1/10000 part in air and in all three cases the bulbs were killed. The bulbs used were of the same kind as in the experiments with ammonia. The bulb decayed invariably from the shoot area toward the center of the bulbs and never from the root area. The outer portion of the bulb looked perfectly natural. The growing point of the shoot was killed in every case. These results are of but little value since the temperature of the plant house fell to 5° C. during one night.

Alcohol.—This reagent seemed to arrest growth. Experiments were set up containing 1/1000 and 1/500 parts of alcohol in 4000 cc. of air. The bulbs were kept under the bell jars for 10 days and when taken out and potted they were perfectly natural. The root areas had begun to swell. No discoloration was noticeable.

TABLE VI.

I. 1/1000 part alcohol in 4000 of air.
II. 1/500 part of alcohol in 4000 of air.
III. Control.

	Growth in mm. when taken from bell jar.	Average growth in 20 days. mm.	Average growth in 30 days. mm.	Average growth in 40 days. mm.	Average growth in 65 days. mm.	Time of first flower.	Number of flowers.
I.	0	25	125	300	660	0	0
II.	0	0	13	20	31	0	0
III.	0	38	175	310	650	50	2

The above table shows a peculiarly interesting result. In the experiment where 1/1000 part of alcohol was used no ill effect on the plants could be detected. The result is more striking in the experiment where 1/500 part of the alcohol was used. The bulbs remained almost stationary and up to February 19, or 100 days from the time the bulbs were placed under the bell jars, the total growth was only 50 mm. Upon an examination it was found that the root system was perfectly natural and well developed, completely filling the four-inch pots into which the bulbs were growing. In dissecting the bulbs the floral structures were found to be very much dwarfed but the bud scales were well developed. The scapes or flower stems were greatly reduced, being only from 5 to 18 mm. in length. The bulbs which were treated with 1/1000 part alcohol showed the same dwarfed condition of the floral organs.

Bulbs of *Arisæma triphyllum*, *Crocus* and Tulip were treated with the various reagents, but no satisfactory result was obtained. All the *Crocus* bulbs died from some unknown cause or causes. The *Arisæma* bulbs were undoubtedly affected by the change in temperature which occurred on the morning of November 23, and to which reference has previously been made.

5. THE INFLUENCE OF GASES UPON GROWTH OF PLANTS GROWN IN NUTRIENT SOLUTION OF WATER CULTURE.

A. *Land plants grown in nutrient solution.* Seedlings of *Zea mais* were used in these experiments and the method described in the introduction was observed. The duration of the experiment was limited to eighteen days. The average growth for this period, taken in four separate experiments in which the seedlings were grown in a nutrient solution saturated with commercial nitrous oxide, was 203 mm. for the roots and 209 for the shoots. The control plants grown in nutrient solution without nitrous oxide showed an average growth of 213 mm. for the roots and 165 mm. for the shoots. The result shows a gain in favor of the nitrous oxide in the shoot and a loss for the root, but the result needs verification.

B. *Aquatic plants grown in river water.* Wide bell jars were inverted and filled with about one inch of soil over which a thin layer of clean sand was spread ; in this substratum several plants of *Philotria* were planted and the bell jar filled about half full of river water. The water in the bell jars was kept saturated with nitrous oxide by means of inverted bottles which were first filled and inserted under water and this water was displaced by nitrous oxide. The bottles were kept in position by means of iron stands. The bottles were refilled as soon as the gas was exhausted.

TABLE VII.

I. *Philotria* in a saturated solution of N_2O.
II. Control.

	Average growth in 5 days. mm.	Average growth in 10 days. mm.	Average growth in 20 days. mm.	Average growth in 30 days. mm.
I.	8	25	53	68
II.	3	9	18.5	29

The marked results shown in the above table were duplicated in all the experiments set up. The average growth of the *Philotria* branches after 28 days taken in another test from four experiments was 17 mm. and the average growth from the control was 11.5 mm.; showing conclusively that nitrous oxide has a stimulating effect on *Philotria*.

To test further the effect of nitrous oxide on aquatic plants, stems of *Salvinia natans*, having an aggregate of 80 leaves were placed in bell jars set up in the same manner as in the previous experiment and the water kept saturated with gas. The experiments were allowed to run for 40 days, when the number of leaves were counted. The control or checks were set up in exactly the same manner as the tests with the exception of nitrous oxide.

TABLE VIII.

I. *Salvinia* in a saturated solution of N_2O.
II. Control.

		Number of leaves at the beginning of the experiment.	Number of leaves at the close of the experiment.	Total gain in number of leaves in 40 days.
I.	a	80	131	51
	a	80	118	38
	a	80	114	34
	a	80	108	28
II.	a	80	99	19
	a	80	104	24

The result of every experiment showed that growth was accelerated by nitrous oxide.

Ammonia was tried on the same water plants under exactly the same conditions as above. One-tenth of a cc. in 2000 cc. of water, and one-five-hundredth of a cc. in 2000 cc. of water were used, but in both cases both the *Salvinia* and *Philotria* plants died.

CONCLUSIONS.

Influence of Gases.

From the foregoing tables and records the following conclusions seem to be warranted:

Nitrous oxide. Seeds of *Phaseolus multiflorus* and *Vicia faba* will not germinate in an atmosphere containing 80% of nitrous oxide. Seedling of *Phaseolus multiflorus* and *Vicia faba* will remain active more than 24 hours in an atmosphere of commercial nitrous oxide, but no growth can take place. Shoots exhibit accelerated growth after being kept in an atmosphere of free N_2O or in an atmosphere where the amount of gas ranges from 25 to 100 per cent. No growth in shoots could be detected during the confinement under the bell jars.

Water plants such as *Salvinia natans* and *Philotria* show increased growth in solutions saturated with N_2O.

Oxygen. Seeds readily germinate in an atmosphere of free oxygen. Seedlings kept in an atmosphere of free oxygen do not grow as rapidly as seedlings in a moist chamber containing ordinary air. Growing shoots kept in an atmosphere containing from 25 to 100 per cent. of free oxygen will remain unaltered as long as 20 days, but on removal slowly perish.

Influence of Vapors.

Ammonia (NOH_4).—Vapors of this reagent when used in quantities not exceeding 1/24000 part are not harmful to the germintion of seeds of *Phaseolus multiflorus.* Seeds exposed for nine days in glass chambers containing from 1/24000 to 1/32000 parts of NOH_4 germinated as freely as the control. The seed of *Vicia faba* is very susceptible to the influence of this reagent and seeds kept in a glass chamber for nine days containing 1/28000 part of NOH_4 failed to germinate. In an atmosphere containing 1/32000 part of NOH_4 90 per cent. of the seed germinated.

Seeds of *Phaseolus multiflorus* and *Vicia faba* kept for nine days in an atmosphere containing 1/20000 of NOH_4 failed to germinate. The growth of young seedlings of *Zea mais* kept in a moist chamber for 48 hours containing 1/20000 part NOH_4 was retarded. Growing shoots are badly affected when kept in an atmosphere containing 1/15000 part of NOH_4. Resting bulbs are not effected by being kept in an atmosphere containing one part of NOH_4 in 5000 of air. *Salvinia natans* and *Philotria* are killed by introducing .1 cc. of NOH_4 to every 2000 cc. of water.

Chloroform and Ether.—These two reagents have a very similar effect upon growth. Seedlings of *Zea mais* kept in a moist chamber containing 1/10000 part of chloroform or ether show a marked acceleration in growth after release. In an atmosphere containing 1/5000 growth is greatly retarded. Resting bulbs and growing shoots are equally susceptible and are killed after being exposed for ten to twenty days in an atmosphere containing 1/10000 part of the reagent.

Carbon bisulphide.—The smallest trace of carbon bisulphide present is injurious to growing plants, although, as G. Hicks (III.) has shown, it is inoperative on resting seeds.

Alcohol has no effect upon the growth of seedlings when used in quantities not exceeding 1/10000. If the larger quantities are used the growth is retarded and the seedlings are killed. Resting bulbs kept in an atmosphere containing 1/1000 to 1/500 parts of alcohol grew, but the floral organs were dwarfed and the buds remained unopened.

LITERATURE TO WHICH REFERENCE IS MADE.

I. Detmer. Ueber die Einwirkung verschiedener Gase insbesondere des Stickstoffoxydulgases auf Pflanzen. Landw. Jahrb.—: 213. 1882.

II. Detmer. Das Verhalten der Pflanzen im Contact mit Stickstoffoxydulgase. Physiol. Prakt. 2 Ed., p. 235. 1895.

III. Hicks. Bull—Bot. Div. Dept. of Agric.—1896.

IV. Johannsen—Bot. Cent.—1896.

V. Moeller. Ueber Pflanzenathmung. I Das Verhalten der Pflanzen zu Stickstoffoxydul. Ber. d. deut. bot. Ges. 2: 35. 1884.

VI. Townsend C. O. Correlation of growth under the influence of injuries. Annals of Botany. 11: 509. 1897.

VIII. SEEDLINGS OF CERTAIN WOODY PLANTS.

FRANCIS RAMALEY.

The following observations on seedlings of woody plants were made at the University of Minnesota, during the years 1896, 1897 and 1898. The plants were grown from seed either collected by the writer, or obtained from reliable dealers.

Most of the species studied have not hitherto been investigated. The author has, however, re-examined some plants described by former investigators, especially in cases where the printed descriptions were incomplete or without illustrations.

The measurements given are in all cases based on a considerable number of plants examined. It has been found that the exact lower limit of the hypocotyl is not always readily determined, although, generally it is enough larger in diameter than the root to be exactly located. It has seemed best in giving the length of the hypocotyl to measure its full extent rather than simply that part above the ground.

An attempt has been made to note, as far as possible, whether the seed coat is carried up or remains underground and also how much the cotyledons increase in size after appearing above the ground. These points have not generally been noted by students of seedlings.

In most cases the length of time required for germination of the seeds is given. The figures are for the first seedlings. Oftentimes plants will appear every few days for over a month after the first have come up. Unless otherwise stated it is to be understood that the seeds were planted in the following spring after ripening. The plants studied will be considered in the order of Engler and Prantl.

SALICACEÆ.

Populus deltoides MARSH.

The seed of the "cottonwood" ripens in June and should be planted at once. The young plants appear above ground in a week or sooner.

The cotyledons are petiolate, the blade being ovate-oblong, about 5 mm. in length and 4 mm. broad. The petiole is about 3 mm. long. There is but little increase in size as the plant grows older.

The first two leaves are opposite, lanceolate, short-petiolate, of willow-like shape. They are about 10 mm. long before the epicotyl has developed at all and do not afterward increase in size. The hypocotyl is 10–15 mm. long; the epicotyl reaches a length of 8 or 10 mm.

The third and fourth leaves are nearly opposite; later ones are alternate. The later leaves become broader and longer petioled, gradually assuming the deltoid form characteristic of the species.

ULMACEÆ.

Ulmus americana Linn.

The "white elm" is a native of the eastern and central United States. The seeds ripen in early spring and must be sown at once. They germinate in about a week. Often, but not always, the pericarp is carried up by the growing seedling.

The cotyledons are at first obovate, slightly auriculate, 5 mm. long and 2–3 mm. broad. They are indistinctly reticulately veined. They increase but slightly in size and seldom become more than 7 mm. long. They are short-petioled. The hypocotyl is slender, not enlarged at the base, 25–35 mm. long, but in time it may reach a length of 50 mm. The epicotyl is about 10 mm. in length.

The leaves are petiolate, ovate, coarsely serrate, with distinct veining. The first two are opposite, the third and fourth nearly so. Later leaves are alternate.

Ulmus fulva Michx.

The "slippery elm," like the previously described species, ripens its seeds early in the spring. These, when planted at once, germinate in about two weeks. The seedling resembles that of *U. Americana* in all essential respects.

Celtis occidentalis Linn.

This is a fine tree native to the central United States and Canada. It is known as the "hackberry." The seeds germinate in from four to six weeks. The seed coat remains under ground.

The cotyledons are at first 10 mm. long, but by the time the first pair of foliage leaves appear they are 30 mm. in length, 17 mm. in width, ovate, entire, notched at the apex. The epicotyl is 10 mm. in length. The figures here given are substantially correct for all the plants examined by the present writer. Lubbock's * figures for seedlings of this species are about one-half those here given.

The epicotyl is at length 20 mm. long. The first two foliage leaves are opposite, the later ones alternate. Leaves of the first year are not at all conspicuously oblique at base as are those of older plants.

MORACEÆ.

Toxylon pomiferum Raf.

This is the well-known "osage orange" of the south-central United States. The seeds germinate in about one month after planting. The seed coat is often carried up by the cotyledons which are thus prevented from opening till they have increased somewhat in size.

When they first appear the cotyledons are 9 mm. long and 5 mm. broad, obovate-oblong, entire, short-petioled. The hypocotyl is stout, 35–50 mm. long.

The cotyledons grow rapidly in size and by the time the first leaves are well developed have increased to 20 mm. in length and 12 mm. in width. The petiole is distinctly margined and 4 mm. long. The veining of the blade is distinct. The epicotyl is 10–15 mm. long. The first two foliage leaves are opposite, narrowly lanceolate, ovate, entire or nearly so, distinctly veined. The later leaves are alternate, often pointed at the base as well as the apex. The seedling of this plant was studied by Lubbock,† but not figured.

Broussonetia papyrifera (Linn.) Vent.

The seeds of this oriental tree, the "paper mulberry," germinate in about three or four weeks after planting. The seed coat is carried up and often remains attached to one of the cotyledons for a time after they have opened.

The hypocotyl is rather slender, 12–15 mm. long. The

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* On Seedlings, 2: 493. 1892.

† Op. cit. 2: 498.

cotyledons are oval; when fully open they have a petiole 2 mm. long and blade 8 mm. long and 5 mm. broad, very slightly notched at the apex. When they first emerge from the seed coat the leaves are not over 5 mm. in length.

The first foliage leaves are opposite; they are petiolate, narrowly ovate, serrate, slightly heart-shaped at base and more nearly entire than the later leaves which are alternate, long-petioled, serrate and frequently more or less two- or three-lobed or parted. Usually about the close of the second season the well-known peculiar characteristic leaves make their appearance.

MAGNOLIACEÆ.

Liriodendron tulipifera LINN.

The seeds of the "tulip tree" germinate in from four to six weeks after planting. The wing-like pericarp remains in the soil.

The cotyledons when they first appear are about 7 mm. long and 5 mm. broad, almost sessile, ovate-oblong in shape. Before the first leaf appears each cotyledon has developed a distinct petiole 2 or 3 mm. long, while the blade is about 12 mm. in length.

The foliage leaves are alternate. The first is broadly ovate-oblong, petiolate, emarginate, with entire margin. The second and third resemble the first. The characteristic leaves appear toward the close of the first season or not till the second year. The epicotyl is extremely short, 1–2 mm. long. Succeeding internodes are likewise short.

CALYCANTHACEÆ.

Butneria florida (LINN.) KEARNEY.

This is the familiar "sweet-scented shrub" commonly cultivated in the eastern United States. It is native from Virginia to the Gulf of Mexico. The seeds require a month or more to germinate. The cotyledons are rolled longitudinally about each other in the seed and remain rolled up for two or three days after appearing above ground.

The hypocotyl is stout, 20 mm. long. Cotyledons are thick, dark green, slightly auriculate at base, petiolate, generally somewhat trapezoidal, the apex broadly incurved. They are at first about 12–15 mm. long and 25 mm. broad. Eventually they may become 20 mm. long and 30 mm. broad with petioles 10 mm. in length. In shape they are often quite asymmetrical.

The foliage leaves are opposite, ovate, pointed, entire. The first do not differ materially from the later ones. The epicotyl is about the same length as the hypocotyl.

Butneria fertilis (WALT.) KEARNEY.

The seedling of this plant does not differ in any important respect from that of the species just described.

CAESALPINACEÆ.

Parkinsonia aculeata LINN.

The seeds of this shrub germinate in about two weeks after planting. The seed coat is usually carried up.

When they first appear the cotyledons are 15 mm. long, 8 mm. broad, ovate-elliptical, sessile, very slightly auriculate at base. The hypocotyl is stout, 30–50 mm. in length. The cotyledons increase in size until they are 25 mm. long.

Foliage leaves are alternate; all are pinnate, the first has five pairs, the second six pairs of leaflets. The epicotyl is 9 mm. long when two leaves have appeared.

Cercis canadensis LINN.

This is the well-known "red bud" or "Judas tree" of the central United States. The seeds germinate in about two weeks. The seed coat is usually carried up, holding the cotyledons together until erect. The veins of the cotyledons are distinct even before the cotyledons have separated.

The cotyledons are broadly ovate, at first 6 mm. long and 4 mm. broad, eventually 15 mm. long and 8 mm. broad. The hypocotyl is stout, 10–30 mm. long. This is of interest since the hypocotyl of *C. siliquastrum* WILLD., as described by Lubbock,* is but 5–6 mm. in length.

The epicotyl is 20–30 mm. long. Foliage leaves are all alternate, entire, cordate, long-petioled.

Gleditsia triacanthos LINN.

The "honey locust," as this plant is called, is a familiar tree of the central United States. The seeds germinate in about one month after sowing. The seed coat is sometimes carried above ground, but it as often remains in the soil.

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* Op. cit. 1: 465.

The hypocotyl is stout, 25–30 mm. in length. The cotyledons are sessile, slightly auriculate, oblong, 18 mm. in length and 9 mm. broad. They do not increase greatly in size.

Leaves are alternate and pinnate. The second appears before the first is fully open. The first leaf usually has eight pairs of leaflets, the second has eleven pairs, the third thirteen pairs. When these leaves have developed the hypocotyl is about 50 mm. long, the epicotyl 20–25 mm.

The first leaves are described by Tubeuf * as having ten pairs of leaflets. In the plants examined by the present writer the first leaf had never more than nine pairs of leaflets.

PAPILIONACEÆ.

Amorpha fruticosa Linn.

This is an ornamental shrub indigenous to North America and frequently cultivated. The seeds germinate in about two weeks after planting.

When the cotyledons first appear they are ovate in shape, about 5 mm. long and 2.5 mm. broad. By the time they are fully open they measure 8 mm. in length. The hypocotyl at this time is 25 mm. long, quite slender, gradually thickened below.

The cotyledons attain a length of 12 mm. They are sessile. The epicotyl is 15 mm. in length. Foliage leaves are alternate. The first five or six are simple, broadly ovate, petiolate. After these the leaves are, for a space, pinnately trifoliate. The terminal leaflet is larger and longer stalked than the lateral ones. Later leaves are pinnate with numerous leaflets.

Amorpha nana Nutt.

The seedlings of this shrub resemble those of *A. fruticosa* save that they are much smaller. The hypocotyl does not become more than 8 or 10 mm. in length and the epicotyl is only about 5 mm. long. Cotyledons are 5 mm. long and 3 mm. broad.

Leaves are alternate. The first six to ten are simple. They are broadly orbicular, emarginate, petiolate, with a distinct midvein. As in the former species the later leaves are pinnately compound.

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* Samen, Früchte und Keimlinge, 12ᵐ. 1891.

The writer is indebted to Mr. D. M. Andrews, of Boulder, Colo., for seedlings of this plant and of *Acer glabrum.*

Robinia pseudacacia Linn.

The "locust tree" is a native of the middle and southeastern United States. The seeds germinate in about two weeks after planting.

Seedlings of this plant were studied by Lubbock [*] and by Flot [†] but the fact is not stated by these writers that the cotyledons are at first somewhat narrowly elliptical or obovate and only at a rather late stage become "oblong-oval." The descriptions hitherto published have not been accompanied by satisfactory figures.

RUTACEÆ.

Ptelea trifoliata Linn.

This is the so-called "hop tree" of the central United States. The seeds germinate in from three to four weeks, the seed coat remaining underground. Almost as soon as the cotyledons get above ground they become erect and then separate.

The cotyledons are nearly sessile, elliptical-oblong, entire, 6 mm. long and 3 mm. broad. They grow for some time and become at length 18 mm. long, 7 mm. broad, minutely serrate, short-petiolate, with midvein distinct. The hypocotyl is rather stout, 15–20 mm. long.

The epicotyl is 20–40 mm. long when the first leaf is fully open. It often elongates somewhat after that time. Leaves are alternate. The first foliage leaf is usually simple, ovate, petiolate, with crenulate margin. Sometimes it is trifoliate, sometimes but partially compound; perhaps one of the side leaflets is separate, but not the other. The second leaf is usually trifoliate, sometimes incompletely so. Later leaves are all trifoliate, the terminal leaflet larger than the lateral ones.

A description of this seedling is given by Lubbock [‡] but there is no figure.

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[*] Op. cit., 1 : 422.

[†] Flot. Recherches sur la structure comparée de la tige des arbres.—Rev. gen. de Bot. 2 : 20. 1890.

[‡] Op. cit. 1 : 322.

SIMARUBACEÆ.

Ailanthus glandulosa Desf.

This well-known tree is a native of eastern Asia. It is, however, grown extensively in this country. The writer's observations on the seedlings differ somewhat from those previously published.*

The seeds, planted in May, germinated in from two to three weeks. The seed coat and wing sometimes remain in the ground but are quite often carried up by the elongation of the hypocotyl before the cotyledons emerge.

The cotyledons are at first about 6 mm. long. By the time they are fully open they have increased somewhat in size and the hypocotyl has attained its full length, viz. about 40 mm. When the first leaves have opened the cotyledons are broadly obovate, petiolate, with the blade 15 mm. long, 11 mm. broad and the petiole 5 mm. long.

The epicotyl is at length 20 mm. long. The first few leaves are trifoliate. Later leaves are pinnate.

ANACARDIACEÆ.

Schinus molle Linn.

This is the so-called "pepper-tree" sometimes planted in California but a native of tropical America. A description of the germination of the seed is given by Lubbock,† whose account in this case, the present writer only desires to supplement.

The cotyledons are remarkable for their great increase in size; beginning with a length of 5 mm. the blade is finally 20–25 mm. long and broad in proportion. The petiole is about 4 mm. in length.

CELASTRACEÆ.

Celastrus scandens Linn.

This is the "climbing bitter-sweet," a common native liana of the United States. It is frequently cultivated. The seeds ripen in the fall. If planted the following spring they usually require a year to germinate.

The cotyledons are thin, reticulately veined, petiolate, oval-oblong in shape. At first they are 10 mm. long and 5 mm.

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* Lubbock op. cit. 1: 327.

† Op. cit. 2: 335.

broad, but grow rapidly and become about twice that size. As they grow older they become broader in proportion to the length. The petiole is finally about 5 mm. long. The hypocotyl tapers gradually to the root so that its exact limit is not easily recognized. It reaches a length of 40 or 50 mm.

The epicotyl is about 15 mm. long. Leaves are all alternate. The first leaves are not different from those formed later.

ACERACEÆ.

Acer negundo Linn.

Seeds of the "box-elder" germinate in from one to two weeks after sowing. The large winged pericarp is brought above ground.

The hypocotyl is 25–35 mm. long when the cotyledons first open and does not grow longer. The cotyledons are strap-shaped, sessile, entire, tri-veined; about 30 mm. long and 5 mm. broad.

The epicotyl becomes 5–8 mm. long. Leaves are opposite. The first two are ovate, acute, serrate, petiolate. Later ones are tri-cleft. Usually the sixth or seventh pair and all later ones are pinnately compound.

Acer glabrum Torr.

The seedling of the "Rocky mountain maple" resembles that of *A. negundo*. The hypocotyl is shorter, 20 mm. long, and the cotyledons about 20 mm. long, 5 mm. broad. Leaves are opposite, long-petioled, ovate-cordate, the second pair somewhat lobed. Later leaves are three- or five-lobed, the lobes more or less acute and sharply serrate.

Acer saccharinum Linn.

The seeds of the "soft maple" germinate in about ten days after planting. The first leaves are well developed when the plant appears above ground. The cotyledons remain in the soil for a time enclosed in the pericarp which eventually decays. Sometimes they do not appear above ground * at all.

The hypocotyl is stout, about 20 mm. long. The cotyledons are somewhat fleshy, asymmetrical, short-petioled, bent around so that both are on the same side of the stem. They are about 16 mm. long and 8 mm. broad.

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* Winkler. Kleinere morph. Mittheilungen, in Verhandl. d. Bot. Ver. d. Provinz Brandenburg, 18 : 99. 1877.

The epicotyl often becomes greatly elongated, reaching a length of 50–100 mm. Leaves are all opposite, those of the seedling are the same shape as the later leaves.

RHAMNACEÆ.

Berchemia racemosa SIEB. & ZUCC.

This plant is a shrub with conspicuously veined leaves. It is a native of Asia. The seeds require two or three weeks to germinate. It is often a number of days before the cotyledons get out of the seed coat which is carried above ground.

When the cotyledons first emerge they are sessile, strap-shaped, 8 mm. long and 1½ mm. broad. They remain about the same size for a time after they are fully open. The hypocotyl is slender, about 15 mm. long.

By the time the first foliage leaves are open the hypocotyl is 15–20 mm. long; the epicotyl 5 mm. in length and the cotyledons 10 or 12 mm. long and 1.5–2 mm. broad. The foliage leaves are ovate, petiolate, conspicuously veined; the first two are opposite or nearly so, all others are alternate.

Rhamnus purshiana DC.

This is a handsome tree of Pacific North America sometimes planted in the eastern United States. The bark is the "Cascara Sagrada" of the drug stores. The seeds require a month or more to germinate.

The cotyledons increase but slightly in size after opening. They are obovate, entire, sessile or nearly so, 7 mm. long and 5 mm. broad. The hypocotyl is 25–30 mm. long.

The epicotyl is slender, 15–20 mm. long. Foliage leaves are ovate, pointed, petiolate, alternate. The first two and the third and fourth are, however, nearly opposite. The margin of the leaf is finely serrate; the veining very prominent.

VITACEÆ.

Vitis cordifolia MICHX.

This is one of the commonest wild grapes found in the northern United States. The seeds germinate readily, the cotyledons appearing above ground in about four weeks. Sometimes the seeds do not germinate till the second year.

The cotyledons are ovate, petiolate, veined. When they first appear the blades are about 10 mm. long and 6 mm. broad. They grow to about 18 mm. in length, and a corresponding width before the first leaves appear, after which time they do not increase in size. The petiole is about 8 mm. long. The hypocotyl is stout, from 25–30 mm. long; it does not grow longer.

The leaves are all alternate, ovate-heart-shaped, irregularly dentate, palmately 5-veined. When the first leaf appears the epicotyl is about 8 mm. long. It may eventually reach a length of 10 or 12 mm.

Parthenocissus quinquefolia (LINN.) PLANCH.

This is the familiar "Virginia creeper," a native of the United States and frequently planted. Seeds germinate in about three weeks.

The hypocotyl is stout, from 20–40 mm. long. The cotyledons are long-petiolate. The blade is cordate, prominently veined, at length 20 mm. long, 20 mm. broad. The petiole is channeled, 20 mm. long. Both hypocotyl and petioles are pink except that part of the hypocotyl which is below ground. The hypocotyl becomes very much thickened toward the end of the season, exhibiting a well-marked "region tigellaire."

The epicotyl is undeveloped, the first leaf arising just above the cotyledons. Leaves are all alternate and quinquefoliate from the beginning. The first do not differ from the later ones.

STERCULIACEÆ.

Sterculia platanifolia LINN.

The seeds of this oriental tree germinate in about a month after planting. A part of the seed coat is often attached to the cotyledons when they first appear above the ground.

The hypocotyl is stout, 40 mm. long at the time the cotyledons open. These are broadly oblong or orbicular, entire, slightly cordate at base, with petioles nearly as long as the blades. The latter are at first about 18 mm. long and 16 mm. broad but become very large, sometimes 40 mm. long and 45 mm. broad. They are palmately five-veined. The midvein forks some distance from the apex.

The epicotyl is about 10 mm. long. Leaves are alternate. The first leaf is broadly heart-shaped, entire, petiolate, palmately five-veined; the midvein runs to the apex of the leaf.

ELÆAGNACEÆ.

Elæagnus umbellata Thunb.

The seeds of this Japanese shrub require about four weeks to germinate. The seed coat is often carried up above ground.

The cotyledons are oblong-ovate, sharply auriculate, short-petiolate. The blades are quite thick. When they first emerge from the seed coat they are 7–8 mm. long but are finally 10 mm. long and 6 mm. broad. The hypocotyl is rather stout, 10–30 mm. long.

The foliage leaves are ovate, entire, petiolate. The first two are opposite or nearly so, later ones are alternate. The epicotyl is short, not usually more than 2 or 3 mm. in length when the first leaves are well developed. It eventually may grow to a length of 4–8 mm.

The seedlings of this plant resemble very much those of *E. angustifolia microcarpa*[*] save that in the latter the petioles of the cotyledons are much longer.

MYRTACEÆ.

Eucalyptus globulus Labill.

This is the well-known "blue gum" tree of Australia. It is planted extensively in California. The seeds germinate in from one to two weeks. The seed coat is often carried up by the cotyledons. These are doubled over each other. One lobe of each is exposed.

The hypocotyl is slender, about 30 mm. long. The cotyledons, when fully opened, are short-petiolate, 3 mm. long and generally twice as broad, two-lobed, the sinus shallow. When first out of the seed coat the cotyledons are about one-half the size here named. No distinct venation was observed, although Lubbock[†] states that they are tri-nerved.

The epicotyl is about 10 mm. long. The foliage leaves are opposite, lanceolate and entire, those higher on the stem becoming gradually broader. Higher internodes of the stem are quadrangular.

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[*] Lubbock, op. cit. 2 : 465.

[†] Op. cit. 1 : 530.

Eucalyptus citriodora Hook.

The mode of germination and the seedling of the "lemon-scented gum" resemble the species just described. There are some important points, however, to be noted.

The hypocotyl is 20 mm. long and quite slender. The cotyledons are petiolate. The blade is broadly orbicular, entire, indistinctly 3-veined; at length 6–9 mm. broad, 4–7 mm. long, green above, red to purple below. The petiole is 3–4 mm. in length. The cotyledons are persistent for a considerable time; often remaining till ten or more nodes of the stem are developed.

Eucalyptus corymbosa Sm.

This plant, also a native of Australia, is called "blood-wood." Seeds germinate in two or three weeks. The hypocotyl is 20 mm. long and quite slender. The cotyledons are short-petiolate. The blade is reniform, deeply cordate at base, at first 2–3 mm. long and 5–6 mm. broad. It finally grows about twice this size and is indistinctly 3-veined.

CORNACEÆ.

Cornus amomum Mill.

The seeds of the common "dogwood" germinate in two or three weeks after planting, but sometimes not till the following year.

The hypocotyl is rather slender and quite long, usually 50 mm. or more in length. The epicotyl also is greatly elongated, reaching a length of 40 mm. The cotyledons are oblong-elliptical, entire, short-petiolate. At first they are 10 mm. long and 5 mm. broad. The blades become 20 mm. long and 10 mm. broad, the petioles 4 mm. long.

Leaves are all opposite, ovate, acute, petiolate. The first are like the later ones.

Cornus stolonifera Michx.

Seedlings of this plant resemble those of the previous species in all essential respects.

Cornus florida Linn.

Seedlings of the "flowering dogwood" resemble those of *C. amomum.*

STYRACACEÆ.

Mohrodendron carolinum (Linn.) Britt.

Seeds of this plant, the "snow-drop tree," planted in the spring of the year following their ripening lie dormant an entire year before germinating.

The cotyledons are thin, oval-oblong in outline, rather short-petiolate. The blades are at first 20 mm. long and 8 mm. broad. They do not increase much in size. The hypocotyl is stout, from 25–35 mm. long.

The epicotyl is about 20 mm. long. The leaves are all alternate, ovate-acute, serrate, petiolate. Save in size there is no difference between the first and the later leaves.

BIGNONIACEÆ.

Tecoma radicans (Linn.) DC.

This is a woody climber, the "trumpet creeper," indigenous to eastern North America and frequently cultivated. The seeds germinate in about ten days. The large flat wing of the seed is sometimes, though not usually, carried up.

The cotyledons are broadly orbicular and deeply notched at the apex. They are almost sessile. When first above ground they are 5 mm. wide, but when fully open are 9 mm. wide. They do not increase in size after that time. The hypocotyl is 20–30 mm. long, green or pale, sometimes pinkish.

The epicotyl is at first quite short, but lengthens, when the foliage leaves open, to about 15 mm. The first leaves are simple, ovate, dentate, petiolate, distinctly veined. The next leaves are tri-foliate. Leaves at length are pinnately compound.

Catalpa speciosa Warder.

This large tree is a native of the southern United States. Seeds germinate in from one to two weeks. The flat winged seedcoat is sometimes carried up, but more usually remains in the soil.

The cotyledons are face to face. They are dark green, deeply bifid, the lobes more or less obovate, 5–6 mm. long and 3–4 mm. broad. They increase rapidly to nearly twice their original size. The hypocotyl is stout, 30 mm. long.

The epicotyl is 8–12 mm. long. Foliage leaves are opposite, entire, pointed, ovate to cordate, petiolate with distinct veining.

Seedlings of this plant have been previously* described, but without measurements or illustrations.

RUBIACEÆ.

Cephalanthus occidentalis Linn.

The "button bush" is a low shrub indigenous throughout most of North America. The seed germinates in about three weeks. The seed coat remains in the ground.

The cotyledons are ovate, acute, short-petiolate, 3 mm. long and 1 mm. broad when they first appear; at length they become about twice or three times that size. The hypocotyl is slender, 15–30 mm. in length.

When the first foliage leaves are open the epicotyl is from 4–8 mm. long. Leaves are opposite, ovate, acute, entire, long-petioled, distinctly veined.

CAPRIFOLIACEÆ.

Sambucus pubens Michx.

This is the "red-berried elder" of the northern United States. The seeds ripen in June. If sown at once they germinate in about one month. Some of the seeds, however, do not come up until the following spring.

The hypocotyl, which passes gradually into the root, is about 10 or 15 mm. long. The cotyledons are petiolate. When they first appear they are 3 mm. long and 2 mm. broad. The cotyledons become longer petioled and the blades more ovate as they grow older. By the time two pairs of foliage leaves have appeared they are 10–15 mm. in length with petiole 8 mm. long.

The epicotyl is very short as are also the succeeding internodes. Leaves are opposite; the first two pairs cordate, serrate, with petioles as long as the blades. The next leaves are generally trifoliate; later ones are pinnately multifoliate.

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*Lubbock, op. cit. 2:335.

GENERAL OBSERVATIONS ON THE FACTS RECORDED IN THE PRECEDING PAGES.

Without any attempt at ecological explanations of the phenomena of the growth and development of seedlings such as given by Goebel* a few generalizations may be made from the plants at present examined. Some of the features to which attention is called have been previously discussed by Klebs† and Lubbock‡ so that what follows will not be so much a consideration of such points but rather a classification of the plants studied with regard to their special peculiarities.

A knowledge of the shape and general structure of the cotyledons does not help one to predict the character of the foliage leaves. Sometimes there is a certain resemblance between cotyledons and the first foliage leaves or even the later ones. The resemblance is, however, chiefly in cases where the cotyledons are ovate or oblong. This is a very common form for foliage leaves as well. Thus in *Toxylon pomiferum* and *Cephalanthus occidentalis* the cotyledons and foliage leaves are much alike. That the two kinds of leaves are of the same general shape, may be a mere coincidence and of no great significance.

Where the general shape of cotyledons and first foliage leaves is much the same, the former may have entire margins and the latter be variously toothed or lobed, *e. g.*, *Vitis cordifolia*, *Ptelea trifoliata*. While, as has been said, there is no absolute agreement in the shape of cotyledons in a given genus or family, nevertheless, there are, as is well known, many families in which certain types of cotyledons prevail. The first foliage leaves, however, are more frequently alike, *e. g.*, *Acer* spp.

In cases where leaves of old plants are pinnately compound the first few foliage leaves are often simple, *e. g.*, *Acer negundo*, *Amorpha* spp., *Ptelea trifoliata*, *Schinus molle*, *Robinia pseudacacia*, *Sambucus* spp. In all these cases the transition to the compound form is gradual. Thus in *Ptelea trifoliata* the first leaf is simple, the second leaf usually has but one lateral leaflet. In *Robinia pseudacacia* the second leaf is trifoliate while later leaves are more and more multifoliate.

Occasionally even the first foliage leaf is compound, as in

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* Organographie der Pflanzen, 1898.

† Beiträge zur Morph. und Biol. der Keimung. Pfeffer's Untersuchungen aus dem Botan. Inst. zu Tübingen 1: 536. 1885.

‡ Op. cit.

Parthenocissus quinquefolia. In *Ailanthus glandulosa*, however, the first few leaves are merely trifoliate while later ones are pinnate. *Parkinsonia* and *Gleditsia* produce pinnate foliage leaves at once, although the earlier leaves have fewer leaflets than those that come afterward.

If the later-formed leaves are not compound but merely lobed or cleft there may be traced a more or less gradual transition to that shape from the entire or more nearly entire first leaves, *e. g.*, *Broussonetia papyrifera*, *Liriodendron tulipifera*.

In nearly all cases where the first two leaves are opposite and the later ones alternate, it is to be noted that the third and fourth are nearly opposite, the fifth and sixth are closer together on the stem than the fourth and fifth or than the sixth and seventh; *e. g.*, *Rhamnus purshiana*, *Eucalyptus* spp., *Ulmus* spp. In other words, the transition from the opposite to the alternate arrangement is usually gradual.

The cotyledons of many species increase considerably in size after they escape from the seed coat; this is particularly noticeable in *Schinus molle*, *Cercis canadensis*, and some others. In other species there is very little increase in the size of the cotyledons after they first appear, *e. g.*, *Rhamnus purshiana*, *Ailanthus glandulosa*.

Cotyledons of rather remarkable shape were noted in the following species: *Celtis occidentalis*, *Catalpa speciosa*, *Eucalyptus globulus*, *Tecoma radicans*, *Acer negundo*, *Berchemia racemosa*, *Butneria florida* and *fertilis*. The first four named have the cotyledons bifid or variously notched or retuse.

Catalpa and *Tecoma*, both Bignoniaceous plants, have very similar cotyledons. The peculiar asymmetrical cotyledons of *Butneria florida* are reproduced exactly in *B. fertilis*. *Eucalyptus globulus*, on the other hand, does not agree at all, in the shape of its cotyledons, with *E. citriodora* and *E. corymbosa*. These have rotund-orbicular cotyledons. The long, narrow cotyledons of *Acer negundo* are quite different from those of *A. saccharinum*. *Berchemia racemosa* has ligulate cotyledons, while in *Rhamnus purshiana*, the only other plant of the same family investigated, the cotyledons are obovate. The large notched cotyledons of *Celtis occidentalis* do not resemble those of the other Ulmaceæ examined. This, is, however, to be expected from the great difference in the character of the fruit in *Celtis* and *Ulmus*.

From the foregoing it may be concluded that broad generalizations in regard to the shape of cotyledons in plant families, cannot be safely made without a considerable mass of data.

EXPLANATION OF PLATES.

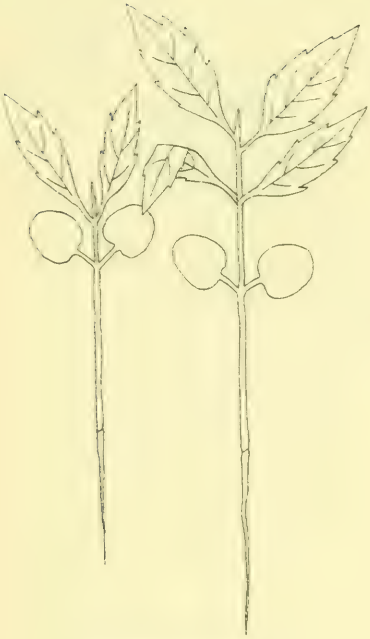
Plate I. Seedlings in various stages of the following plants: *Populus deltoides*, *Ulmus americana*, *Celtis occidentalis*, *Toxylon pomiferum*, *Broussonetia papyrifera*, *Liriodendron tulipifera*, *Butneria florida*, *Parkinsonia aculeata*.

Plate II. Seedlings in various stages of the following plants: *Cercis canadensis*, *Amorpha fruticosa*, *Amorpha nana*, *Robinia pseudacacia*, *Ptelea trifoliata*, *Ailanthus glandulosa*, *Schinus molle*, *Celastrus scandens*.

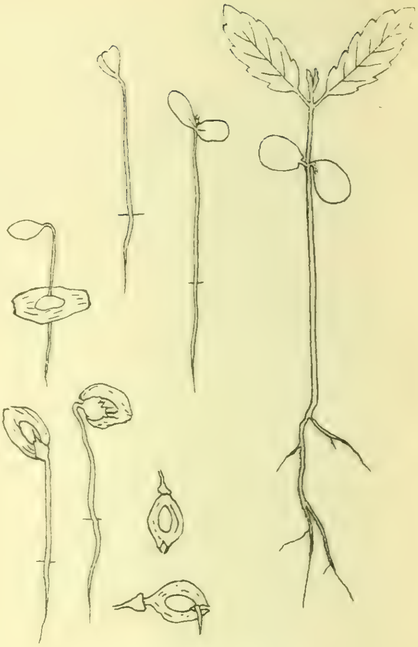
Plate III. Seedlings in various stages of the following plants: *Acer negundo*, *Acer saccharinum*, *Acer glabrum*, *Berchemia racemosa*, *Rhamnus purshiana*, *Vitis cordifolia*, *Parthenocissus quinquefolia*, *Sterculia plantanifolia*.

Plate IV. Seedlings in various stages of the following plants: *Elæagnus umbellata*, *Eucalyptus globulus*, *Eucalyptus citriodora*, *Cornus amomum*, *Mohrodendron carolinum*, *Catalpa speciosa*, *Tecoma radicans*, *Cephalanthus occidentalis*, *Sambucus pubens*.

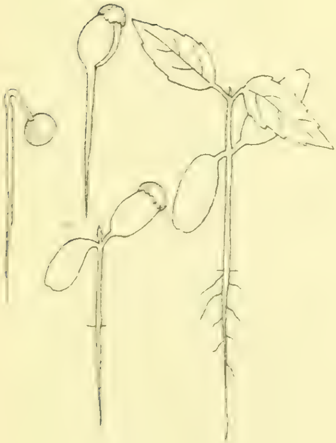
The amount of enlargement or reduction is indicated for each plant.



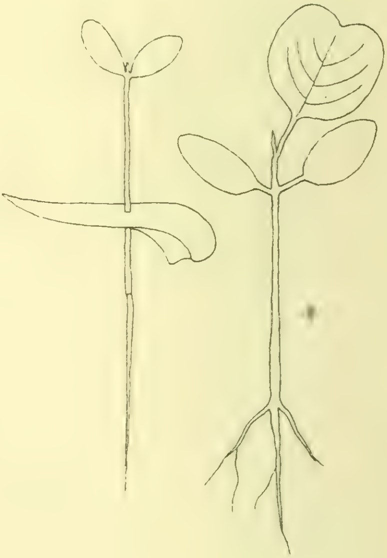
Populus deltoides x 1½



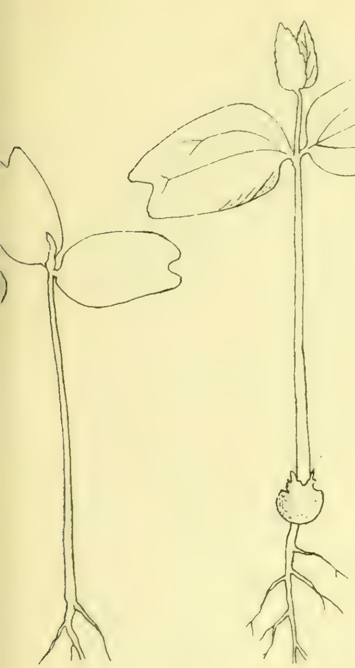
Ulmus americana x ¾



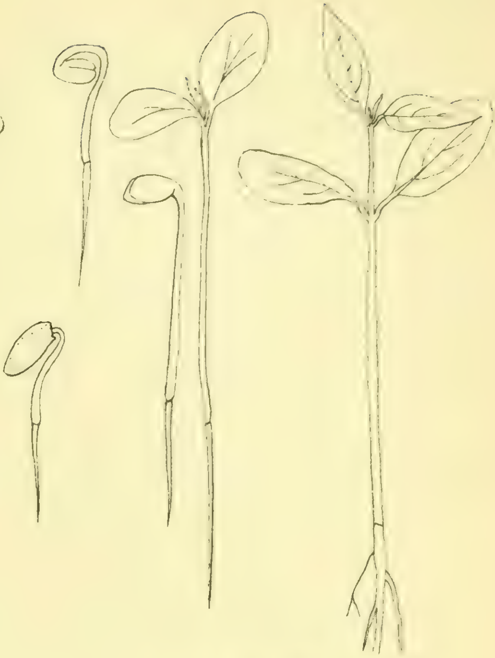
Broussonetia papyrifera x 1½



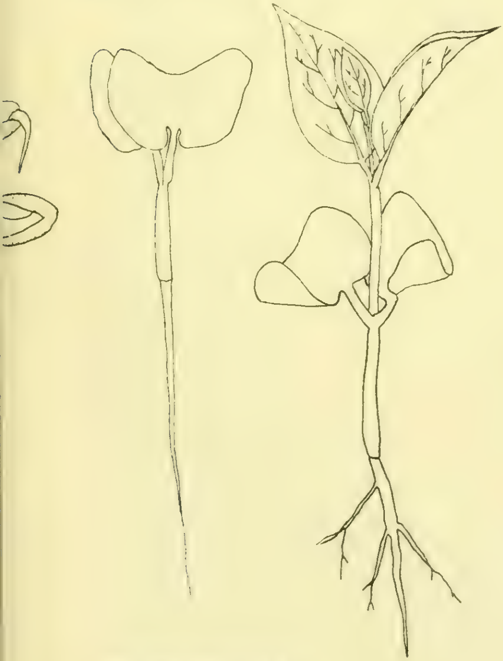
Liriodendron tulipifera (natural size)



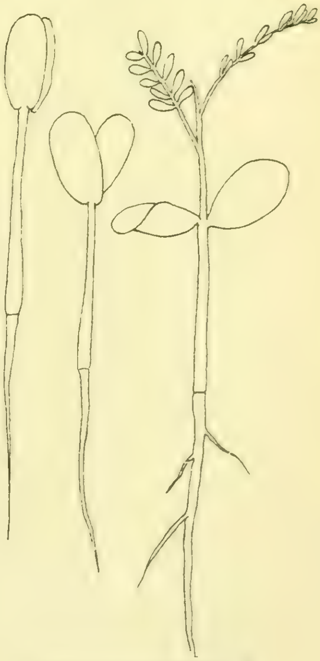
Celtis occidentalis x $\frac{3}{4}$



Toxylon pomiferum x $\frac{3}{4}$



Butneria florida x $\frac{3}{4}$



Parkinsonia aculeata x $\frac{3}{4}$

TE I.

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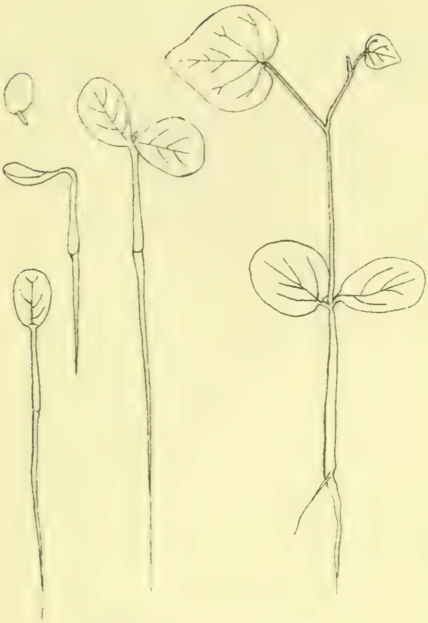
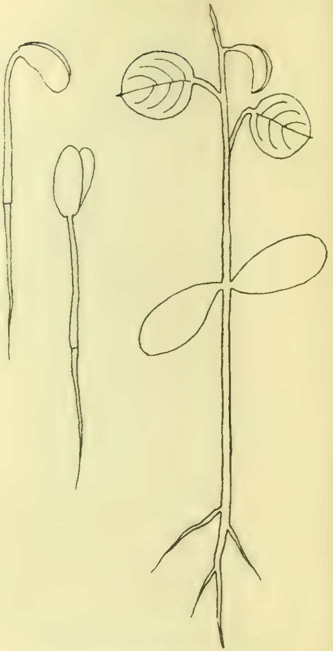
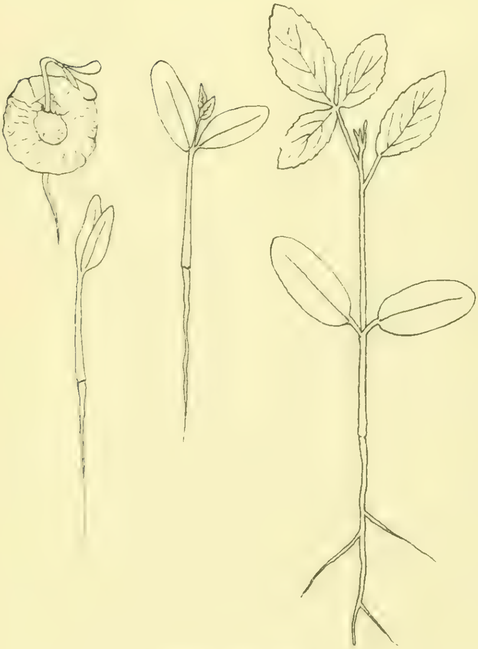


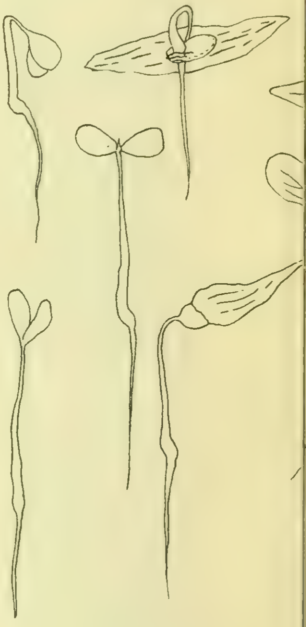
Cercis canadensis x ¾



Amorpha fruticosa x 1½

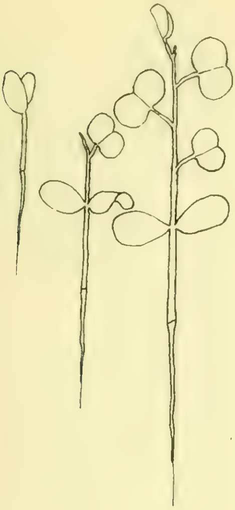


Ptelea trifoliata x ¾

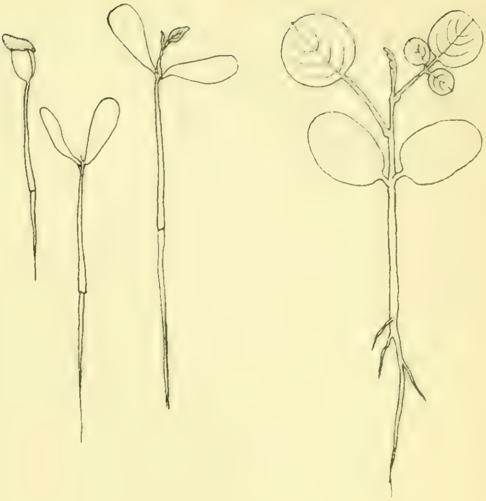


Ailanthus glandulosa x

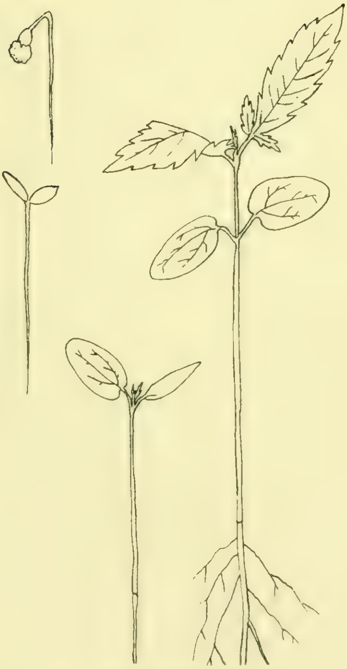
HELIOT



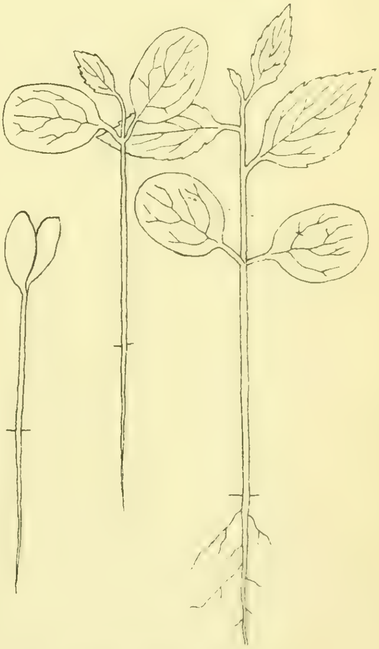
Amorpha nana x 1½



Robinia pseudacacia x ¾



Schinus molle x ¾



Celastrus scandens x ¾

TE II.

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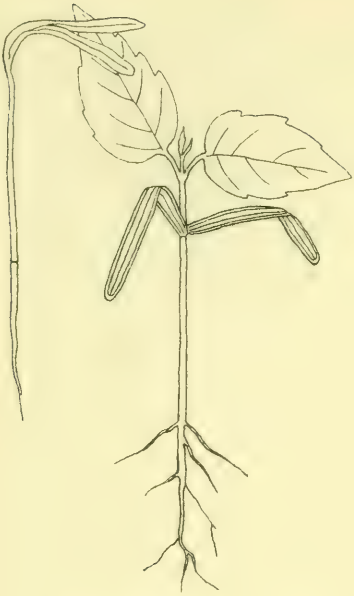
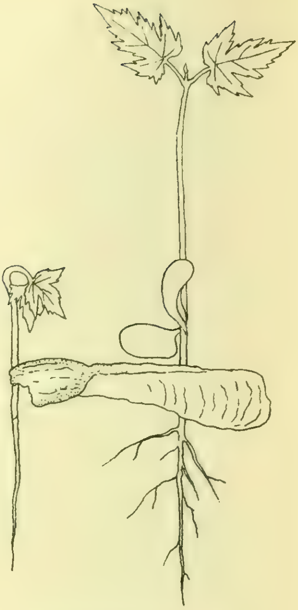
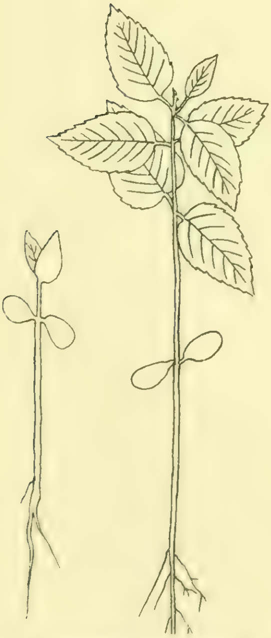


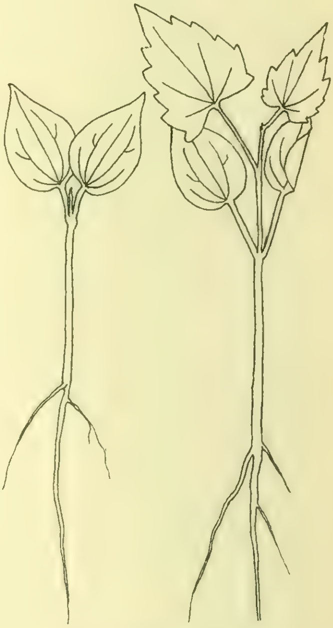
Acer negundo x $\frac{3}{4}$



Acer saccharinum x $\frac{3}{4}$

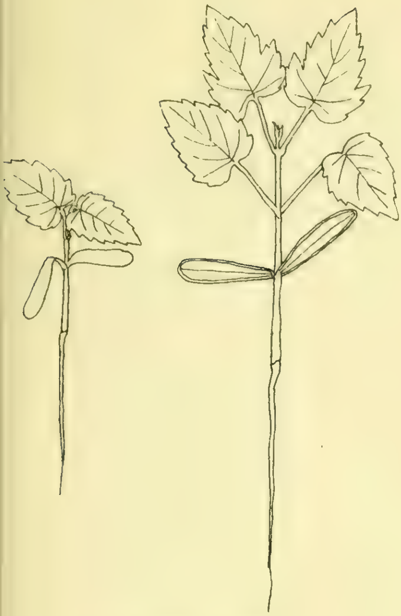


Rhamnus purshiana x $\frac{3}{4}$

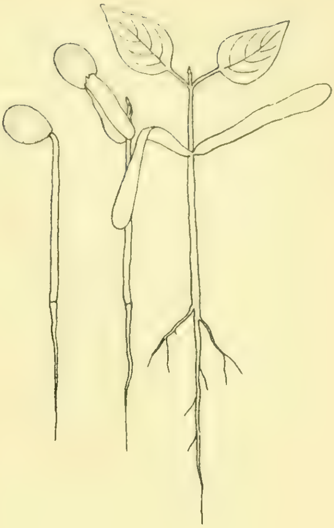


Vitis cordifolia x $\frac{3}{4}$

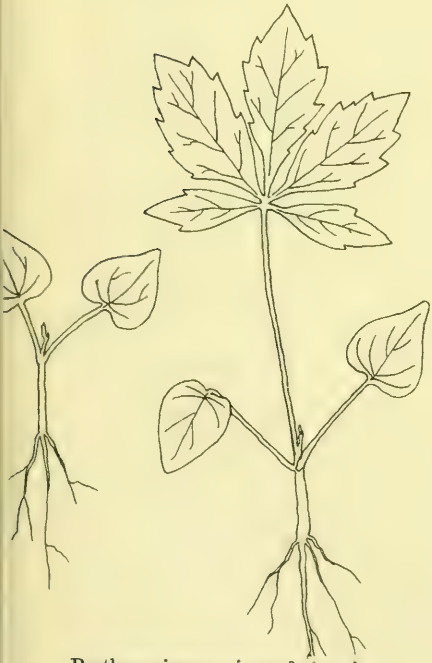
HELIOTYPE



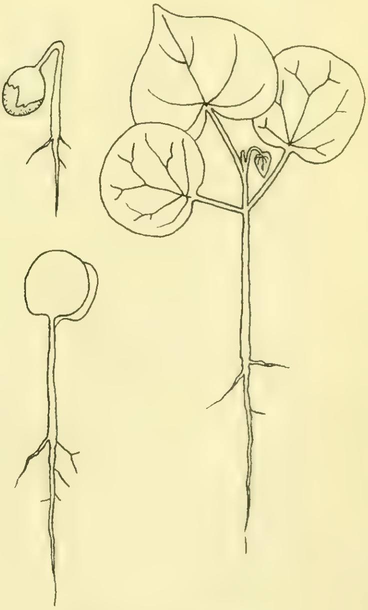
Acer glabrum x ¾



Berchemia racemosa x 1½



Parthenocissus quinquefolia x ⅓



Sterculia platanifolia x ⅓

III.

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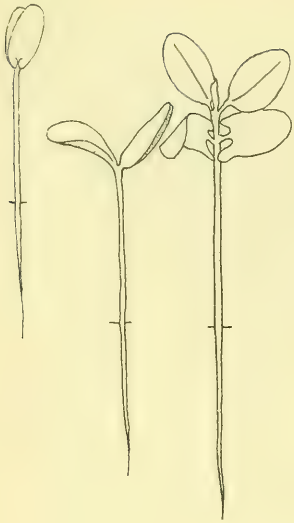
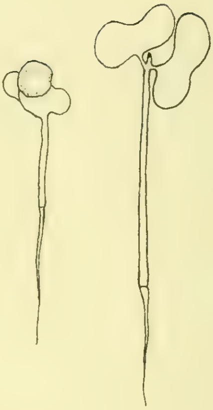
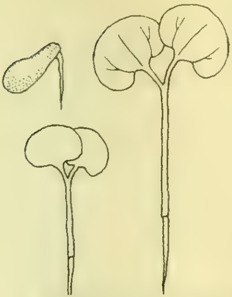


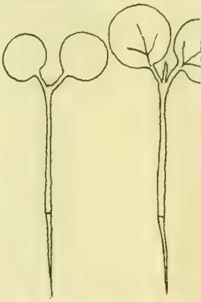
Elaeagnus umbellata x 1½



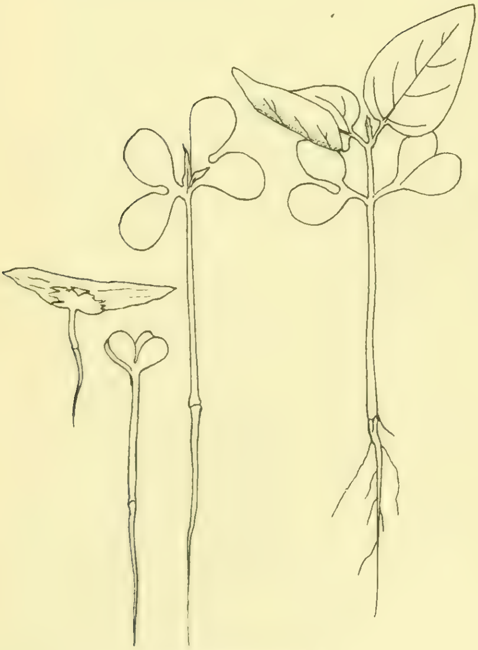
Eucalyptus globulus
(natural size)



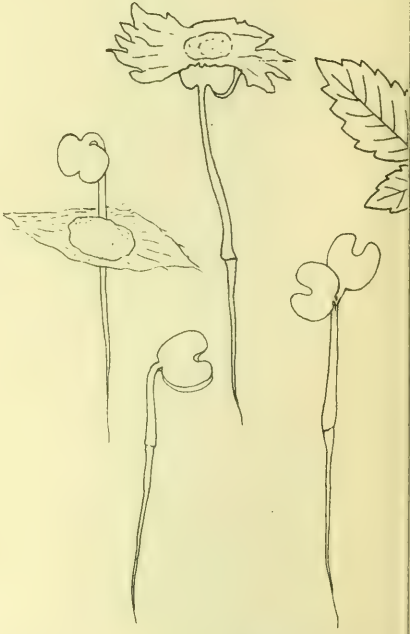
Eucalyptus corymbosa
(natural size)



Eucalyptus citriod
(natural size)

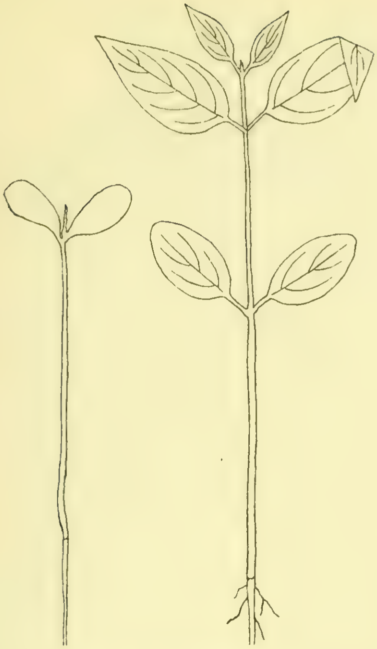


Catalpa speciosa x ¾

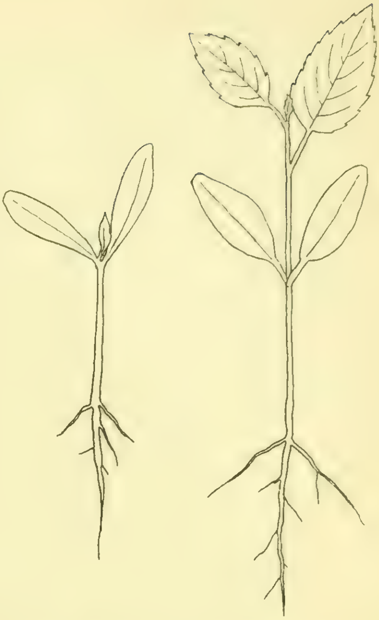


Tecoma radicans x

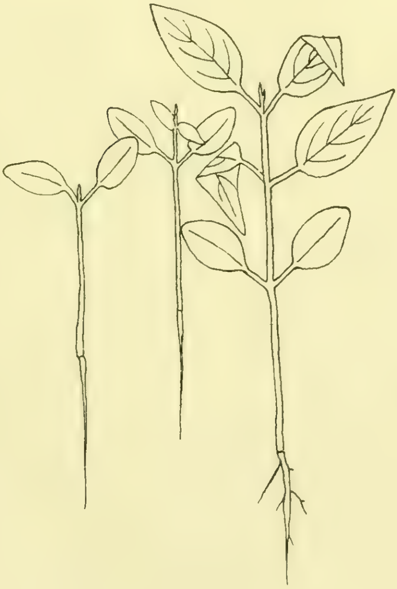
HELIOTYPE



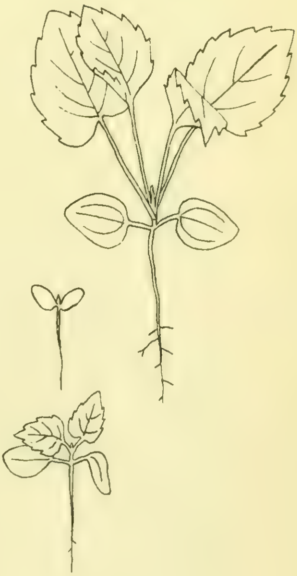
Cornus amomum x $\frac{3}{4}$



Mohrodendron carolinum x $\frac{3}{4}$



Cephalanthus occidentalis x $1\frac{1}{2}$



Sambucus pubens x $\frac{3}{4}$

E IV.

CO. BOSTON

IX. COMPARATIVE ANATOMY OF HYPOCOTYL AND EPICOTYL IN WOODY PLANTS.

FRANCIS RAMALEY.

The following is an account of the anatomy of seedlings of certain woody dicotyledonous plants. These plants were studied: *Ulmus americana* LINN., *Celtis occidentalis* LINN., *Toxylon pomiferum* RAF., *Broussonetia papyrifera* (LINN.) VENT., *Liriodendron tulipifera* LINN., *Menispermum canadense* LINN., *Butneria florida* (LINN.) KEARNEY, *Parkinsonia aculeata* LINN., *Cercis canadensis* LINN., *Gleditsia triacanthos* LINN., *Amorpha fruticosa* LINN., *Robinia pseudacacia* LINN., *Ptelea trifoliata* LINN., *Ailanthus glandulosa* DESF., *Schinus molle* LINN., *Berchemia racemosa* SIEB. & ZUCC., *Rhamnus purshiana* DC., *Vitis cordifolia* MICHX., *Elaeagnus umbellata* THUNB., *Eucalyptus globulus* LABILL., *Tecoma radicans* (LINN.) DC., *Catalpa speciosa* WARDER, *Cephalanthus occidentalis* LINN. The order in which they are described is that of Engler and Prantl. This order will be followed throughout.

The author is under obligation to Professor Conway MacMillan, who suggested the subject of the investigation and under whose direction the work has been completed.

The seedlings were grown at the University of Minnesota during the years 1896, 1897 and 1898. They were examined at different ages so that the original structure of both hypocotyl and epicotyl could be noted as well as the differences brought about through secondary changes.

For the sake of convenience and uniformity three stages were studied; these may be designated as first, second and third stages. A seedling with the cotyledons expanded but with the epicotyl undeveloped is said to be in the first stage. Obviously only the structure of the hypocotyl was studied in this stage. In the second stage the epicotyl has elongated and the first foliage leaves have appeared. In the third stage a considerable number of foliage leaves have been developed and the anatomical structure has, to a considerable extent, taken on its permanent characters. Sections were also, in many cases, cut from material two years old for purposes of comparison.

Since the structure of the hypocotyl is often materially different in all the three mentioned stages, it has seemed important to make a record of the changes which take place during the first year's growth. Previous investigators have not done this.

A number of investigators who have made a comparative study of root and shoot have incidentally examined the hypocotyl, *e. g.*, Goldsmith [1876] and Gérard [1880 and 1881]. The latter made some careful observations on the course of vascular bundles from the cotyledons to the root. His statement that the characteristic root structure often extends as high as the cotyledons is not, in general, confirmed by the present investigation.

The most important articles* which need to be mentioned at the present time are by Dangeard [1888 and 1889], Van Tieghem [1891], and Flot [1889 and 1890]. Dangeard begins with a study of the structure of roots, of which he distinguishes three types. In the first type the root is diarch; the hypocotyl has four bundles in two pairs which arise as cotyledonary trace bundles by the division of the midrib of each cotyledon. In the second type the root is tetrarch; the hypocotyl has eight bundles in four groups. In the third type the root is octarch, while the hypocotyl has sixteen bundles in eight groups. The first type of structure of the hypocotyl above mentioned is the one commonly found in the plants studied by the present writer who has called it the "typical structure." (See General Conclusions at the close of this paper.)

Flot [1889, 1890] describes the "region tigellaire," a much thickened portion of the axis of certain year-old seedlings. The region extends from the base of the hypocotyl up to the first foliage leaf or to some point between that and the cotyledons. It is noted only in certain species. It is not the same as the "tigelle," which extends only as high as the cotyledons. The "region tigellaire" is characterized by only a slight development of sclerenchyma and of normal phloem, while internal phloem is probably altogether absent. The pericycle, he says, is well developed.

Van Tieghem [1891] divides the hypocotyl into "tigelle" and "rhizelle." The growth of the hypocotyl is produced by the elongation of either the tigelle, as in *Ricinus*, *Acer*, *Cucur-*

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*Search has been made, but without success, for a paper by Monal: Rech. sur l'anat. compar. de la tige hypocot. et epicot.

bita, *Tagetes*, *Convolvulus* and *Mirabilis*, or, the rhizelle, as in Ranunculaceæ, Cruciferæ, Caryophyllaceæ, Chenopodiaceæ, Umbelliferæ, Rubiaceæ and Coniferæ, or by a combination of the growth of both as in *Euonymus*.

The designation of certain regions as tigelle, rhizelle and tigellaire does not seem to the present writer a matter of great importance in the plants which he has studied, for in them these regions are by no means sharply differentiated. Further observations and references to the work of Flot mentioned above are given in the pages which follow.

In the special portion of the present work will be found descriptions of the structure of hypocotyl and epicotyl in the various species examined. Accompanying each description is a diagram of the cross section of the hypocotyl when the seedling is in the first stage previously described, and diagrams of both hypocotyl and epicotyl of the second and third stages. In these diagrams stereom is black, xylem is dotted, cortex, phloem, pericycle and the pith are white. The endodermis, when distinct, is indicated by a single line as is also the epidermis and the boundaries between the various zones. In each figure the diagrams of the hypocotyl are at the left, those of the epicotyl at the right.

ULMACEÆ.

Ulmus americana.

Structure of Hypocotyl.

The epidermis is composed of cells which, in cross section, are square or rounded. After secondary growth of the stele has commenced these cells become very much flattened. There is no hypoderma differentiated. The cells of the cortex are large ; all are about the same size.

The endodermis is small-celled and is easily recognized in early stages, when it contains very little starch. Afterward starch becomes abundant in the endodermis, pericycle, cortex, phloem and inner xylem.

In the stele there are many small phloem bundles which are confluent into two crescent-shaped areas. There are two xylem bundles of somewhat crescentic appearance in cross section. The xylem and phloem soon form closed rings.

The pericycle, in seedlings which have about two internodes of the stem developed, is partially sclerenchymatous. At a later time numerous groups of sclerenchyma are found in the phloem and cortex.

The pith becomes quite small. There is a small-celled perimedullary zone.

The formation of cork cambium, as noted by Flot ([1890], p. 29), takes place in the inner cortex.

Structure of Epicotyl.

The cells of the epidermis when seen in cross section, are somewhat rectangular in outline. The tangential diameter is the longer. Numerous hairs are present. No collenchymatous hypoderma is produced. The cortex is rather narrow. The cells are all about the same size.

The endodermis is distinct only in young material. The cells are small. They contain starch. At the end of the season starch is found in the pith and inner xylem and is sparingly distributed in the cortex and phloem.

In the youngest material examined the phloem forms a closed ring surrounding a number of xylem groups. There are usually eight of these. They soon fuse to form a complete ring.

Numerous small groups of thick-walled cells finally make their appearance in cortex, pericycle and phloem.

The pith becomes quite small. The cells have thin unlignified walls. The perimedullary zone is easily distinguished; it consists of from one to three layers of small cells which are often somewhat flattened.

Cork formation, as is well known in this species, begins in the outermost cell layer of the cortex.

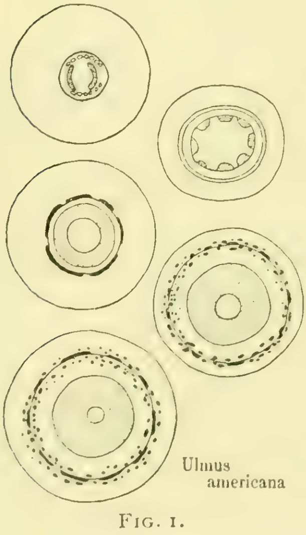


FIG. 1.

Comparison of Structure of Hypocotyl and Epicotyl.

The epidermal cells of the hypocotyl in young material appear radially elongated, those of the epicotyl tangentially elongated. The former region has a thicker cortex, fewer epidermal hairs, sclerenchyma developed earlier in the pericycle.

The stele of the hypocotyl has two xylem bundles and two aggregations of phloem bundles. In the epicotyl the youngest material examined has a complete ring of phloem and about eight xylem bundles. Cork formation in the former region takes place deep in the cortex instead of in the outermost cortical layer.

In their final structure the two regions are practically alike.

Celtis occidentalis.

Structure of Hypocotyl.

The epidermis is composed of thin-walled cells, small, square in cross section. There is no hypoderma. The elements of the cortex are large. There are about twenty layers of cells.

The cells of the endodermis are much smaller than those of the cortex and on this account the endodermis is readily distinguished until considerable secondary growth of vascular tissue has taken place.

Starch is found in the endodermal region from the first; toward the close of the season it is found not only in the pith, phloem and cortex, but very abundantly distributed throughout the xylem. Large isodiametric crystals, long known in the stem of this species (Moeller [1882], p. 74), make their appearance in the cortex some time before the close of the first season.

The stele, which is cylindrical from the first, has originally four xylem bundles and two crescentic masses of phloem. At an early stage the xylem forms a closed ring, while it is not till sometime afterward that the two areas of the phloem become united.

Two interrupted rings of sclerenchyma appear later in the first season, one of these is in the cortex and consists of much larger groups of cells than does the other which is in the outer phloem.

The pith is large-celled. A more or less definite perimedullary zone of small cells is at length developed.

Cork formation begins at a late period in the outermost cell layer of the cortex.

Structure of Epicotyl.

The cells of the epidermis are at first nearly square in cross section but at a later time are considerably flattened. There are numerous simple curved and pointed hairs; there are also some with bulbous ends.

The cortex is thin. A distinct collenchymatous hypoderma is developed. It usually consists of three or four layers of cells.

The endodermis, which is originally distinct, soon becomes unrecognizable. The cells are about the same size as those of the cortex; they contain starch. Eventually all the parenchymatous elements contain starch.

The stele is originally somewhat elliptical in cross section. The phloem, in the youngest material examined, forms a complete ring. There are generally two large and four small xylem bundles. These soon fuse to form a closed xylem zone.

An interrupted band of sclerenchyma is developed at the outer limit of the xylem.

As in *Celtis australis* (cf. Flot [1893], p. 68) there is a distinct perimedullary zone composed of two or three cell rows.

Cork formation begins, rather late in the season, in the outermost hypodermal layer (cf. Moeller [1882], p. 74).

Comparison of Structure of Hypocotyl and Epicotyl.

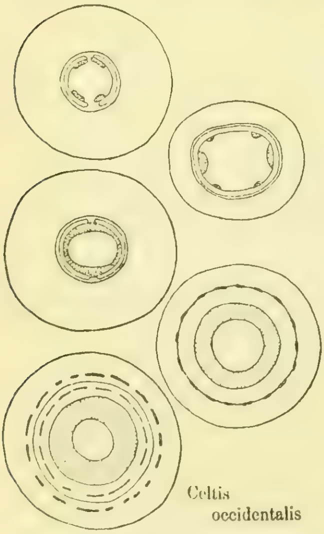


FIG. 2.

A striking difference between hypocotyl and epicotyl is the absence from the former region of the numerous epidermal hairs so abundant in the latter. The hypocotyl is without a hypoderma.

The primary stelar structure of the hypocotyl is peculiar, the phloem forming two crescentric masses and not uniting into a closed ring till after the xylem bundles have fused. The epicotyl possesses a ring of phloem and six xylem bundles.

At the end of the season the hypocotyl has two interrupted bands of sclerenchyma instead of one, and a smaller pith. Aside from these differences the two regions are the same in structure.

MORACEÆ.

Toxylon pomiferum.

Structure of Hypocotyl.

In cross section the cells of the epidermis appear radially elongated. Eventually they are considerably flattened. The cells of the outer cortex are similar to those of the epidermis. There is no collenchyma developed. The inner cortex is composed of larger cells.

The endodermis is distinct but in material taken at the close of the growing season it was not distinguished. The development of pericycle is remarkable. This region is composed of about six layers of parenchymatous cells resembling, in shape, those of the endodermis.

Starch is found, from the first, in the endodermis and later appears in all the conjunctive tissues.

The stele is slightly four-angled. There are, in the youngest material examined, four xylem bundles and two large crescent-shaped phloem bundles. The phloem soon forms a complete ring as does also the xylem, but the two xylem bundles first fuse in pairs.

About this time four aggregations of small groups of sclerenchyma appear in the pericycle. Eventually a nearly complete sclerenchymatous ring surrounds the phloem.

The pith is large-celled. A small-celled perimedullary zone of three or four layers is present.

Cork formation takes place in the fourth or fifth layer of the cortex.

Structure of Epicotyl.

The epidermis is composed of cells which are, at first, nearly square in cross section but later are very much flattened. According to Moeller [1882] the epidermis is two-layered. Numerous straight epidermal hairs are present; there are also some stalked glandular hairs. The cells of the cortex are rather small, parenchymatous, not at all collenchymatous.

The endodermis is distinguished with difficulty even in very young material. Its cells contain starch. Starch is later found in all the parenchymatous tissues.

There is a variable number of vascular bundles; usually eight to sixteen. These soon fuse to form closed rings of phloem and xylem.

An interrupted sclerenchymatous ring is formed at the outer edge of the phloem; the cells are thick-walled but do not become lignified the first year.

The pith is rather large. There is a small-celled perimedullary zone which is quite definite.

Cork formation in the epicotyl takes place in the outermost cortical layer (cf. Moeller [1882]).

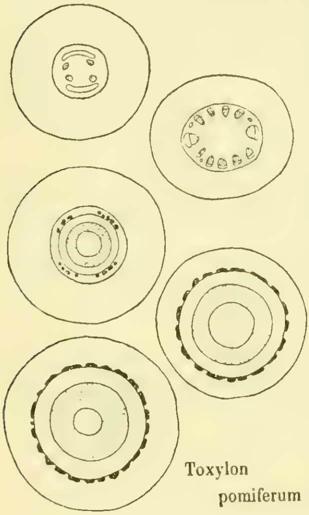
Comparison of Structure of Hypocotyl and Epicotyl.

In the hypocotyl the cortex and pericycle are much better developed than in the epicotyl. The former region is without epidermal hairs. This point of difference was previously noted by Klebs [1885].

The stele of the hypocotyl has originally four vascular bundles, instead of from eight to sixteen; the pith is small in extent.

The sclerenchyma is first formed in four patches but afterwards forms almost a complete ring. Cork formation in the hypocotyl begins in a deeper layer of the cortex.

At the close of the year the two regions have nearly the same structure, about the only difference being the size of the pith.



Toxylon pomiferum

FIG. 3.

Broussonetia papyrifera.

Structure of Hypocotyl.

There is an epidermis of small cells nearly square in outline when seen in cross section. These cells become greatly elongated tangentially as the tissues within increase in thickness. Short, blunt, unicellular epidermal hairs are numerous.

The cortex is composed of about six layers of large, thin-walled parenchymatous elements which, like the epidermal cells, become stretched toward the close of the season.

The endodermis is small-celled. It sometimes remains distinct till nearly the close of the first season. Starch is present in the endodermis, but absent from all other tissues for a long time. It eventually appears in the pericycle, phloem, medullary rays and inner elements of the xylem.

The stele is originally very small. In the disposition of the vascular tissues this plant differs from all others examined by the writer. In cross section the center of this stele is seen to be occupied by an elongated area of xylem. On each side of this, separated by a small amount of conjunctive tissue, is a crescent-shaped mass of phloem. The xylem soon forms a somewhat four-sided mass, and is surrounded by a ring of phloem. The xylem at length becomes circular, and the surrounding phloem increases greatly in amount.

There is but slight development of stereom, although, toward the close of the first season, numerous isolated sclerenchymatous elements are found in the phloem.

The cork cambium originates in the endodermis or pericycle. The ring of phellogen is sometimes irregular, appearing now in one, now in the other of the regions named.

It may be said that, since the structure of the hypocotyl in this species so much resembles the general type of root structure, it was thought best to examine a large number of plants, lest the peculiarities noted should have been due to teratological development. All the plants were, however, found to be alike. Neither is there any trouble in this species, to determine the lower limit of the hypocotyl, for it is enlarged below and does not gradually shade off into root, as is the case in some seedlings.

Structure of Epicotyl.

The epidermis is small-celled. There are numerous simple, blunt and pointed hairs, and also some with a single stalk cell and a multicellular bulb at the distal end.

A somewhat collenchymatous hypoderma is developed, consisting of two or three layers of cells, which are smaller than the deeper cells of the cortex.

The small-celled endodermis, at first distinct, soon becomes displaced and changed, owing to secondary growth of sub-lying tissues.

Starch is almost entirely absent, except in the endodermal region, till about the close of the first growing season, when it appears in the pith, medullary rays, phloem and, to a slight extent, in the cortex.

The stele is large. There is a circle of twelve to eighteen conjoint vascular bundles. These soon fuse to form a narrow zone each of xylem and phloem.

There is a considerable amount of sclerenchyma at the outer edge of the phloem. The cells are, however, mostly isolated or else occur in small groups.

The pith, which is extensive, is composed of large, parenchymatous elements with thin, slightly lignified walls. According to Flot [1893], there is a perimedullary zone of five or six layers of crushed, thin-walled cells. The same author states that laticiferous tubes are found in the perimedullary region of young twigs of this species.

The cork cambium is formed in the outermost hypodermal layer (cf. Moeller [1882], p. 82).

Comparison of Structure of Hypocotyl and Epicotyl.

Both hypocotyl and epicotyl have simple epidermal hairs, but the former does not have the pointed or the bulbous hairs found in the latter region. The hypocotyl is also without the somewhat collenchymatous hypoderma found in the epicotyl; its endodermis persists for a greater length of time.

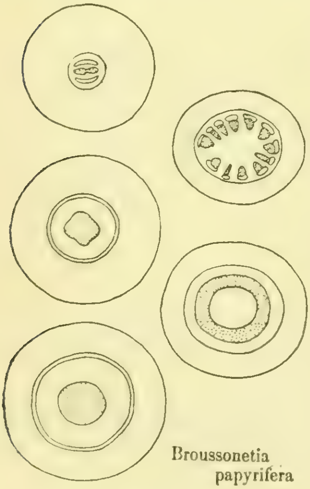


Fig. 4.

The structure of the stele in the hypocotyl is anomalous. A single flat bundle of xylem is flanked by phloem, which eventually surrounds the centrally-lying xylem, the inner cells of which contain starch. There is no pith. The epicotyl, on the other hand, has a large pith, and the vascular bundles are originally numerous. Starch is absent from the xylem.

Cork formation is endodermal or pericyclic in the hypocotyl, but hypodermal in the epicotyl.

MAGNOLIACEÆ.

Liriodendron tulipifera.

Structure of Hypocotyl.

The epidermis consists of cells which are nearly square in cross section; at first they are very much bulged. They never become flat. The two or three layers of the cortex just below the epidermis are small-celled. The deeper layers are very large-celled.

The endodermis is small-celled and easily distinguished in young material, but is eventually displaced and is not distinguishable. In the young stages starch is entirely absent from the hypocotyl, but later is found sparingly distributed through the various parenchymatous tissues.

The stele, which is originally quadrangular, has four vascular bundles arranged in pairs. By their continued growth zones of xylem and phloem are produced.

About the time that a complete ring of xylem has been formed four masses of sclerenchyma appear in the pericyle. Eventually other groups of pericyclic cells also become sclerotic. The phloem immediately under these groups is better developed than at other places.

The pith is slightly quadrangular. The cells are thin-walled. A definite perimedullary zone was not distinguished.

The cork cambium is produced in the outermost layer of cortical cells.

Structure of Epicotyl.

The cells of the epidermis, when seen in cross section, appear square or tangentially elongated. A narrow collenchymatous hypoderma is developed. The remaining cells of the cortex are all about the same size.

The endodermis is distinct in young material, owing to the presence of starch in its cells. At a later time starch is distributed in small amount in the various parenchymatous tissues.

The number of primary xylem groups in the stele is about six or eight. Groups of phloem are somewhat more numerous. Closed zones of xylem and phloem are produced very early.

The outer phloem has many groups of sclerenchymatous fibers. These groups are close together, separated only by medullary rays. A small amount of sclerenchyma is produced in the cortex.

The pith is rather large, and composed of cells with thin, unlignified walls. No perimedullary zone was distinguished.

Cork is developed in the outermost cell layer of the cortex (cf. Moeller [1882], p. 229).

Comparison of Structure of Hypocotyl and Epicotyl.

The cortex of the hypocotyl is much thicker than that of the epicotyl. The former region has no hypoderma; it has four vascular bundles instead of six or eight or more; the sclerenchyma first appears in only four groups and at no time is as well developed as in the epicotyl.

The pith of the hypocotyl is smaller than that of the epicotyl; it is somewhat quadrangular in shape.

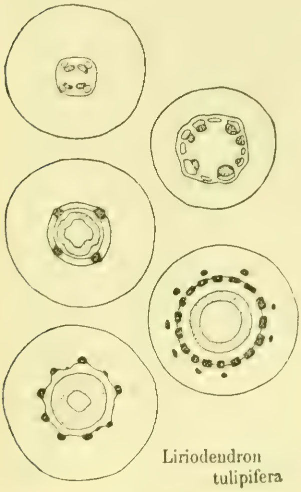


FIG. 5.

MENISPERMACEÆ.

Menispermum canadense.

Structure of Hypocotyl.

The epidermis consists of cells which are square or rectangular in cross section. Late in the first season they become flat and tangentially elongated. A very thick, tough cuticle develops at the same time.

There is no hypoderma. There are about twelve layers in the cortex. The cells are large.

The endodermis consists of cells smaller than those of the cortex. It remains distinct a long time, but was not distinguished in material taken at the close of the growing season. The pericycle is peculiar. It is one or two layers in thickness. Usually every second or third cell, when seen in cross section, is without starch, although starch is present in the other cells. Eventually these cells also contain starch.

This plant is somewhat unique in the distribution of starch in its tissues, for in all the different stages examined starch was found in cortex, pith, endodermis and medullary rays and in the pericycle except as just noted.

The stele is quadrangular and has four primary vascular bundles. These increase considerably in size as the plant grows older. At the close of the growing season they are of about the same extent as the medullary rays which are composed of wood parenchyma and are full of starch. There is no phloem produced the first year opposite the medullary rays.

The pith is composed of large cells. There is a rather distinct smaller-celled perimedullary zone. No cork is formed the first year.

Structure of Epicotyl.

The cells of the epidermis, at first square in cross section, become very much flattened and develop a thick cuticle like that of the hypocotyl. A more or less definite collenchymatous hypoderma is developed. The cortex is composed of about six cell layers.

The endodermis is not easily distinguished even in youngest stages. The pericycle has some cells which in cross section appear empty, while the neighboring cells contain starch. These empty cells at a later time either become filled with starch or else are displaced so that they are not recognized.

Starch is present in the cortex, medullary rays, endodermis, pericycle and pith.

There are originally from nine to fifteen vascular bundles. These usually fuse to some extent so that there come to be only about six or eight. These remain easily distinguishable, since the primary medullary rays are very broad. The growth of the cambium produces no true phloem elements opposite the medullary rays, although there is some thin-walled parenchyma.

A crescent-shaped area of stereom is finally formed at the outer edge of each phloem bundle.

The pith becomes rather small in extent. There is a perimedullary zone of two or three layers of smaller cells. According to Flot [1893] these form at a later time five or six layers of sclerotic parenchyma. The formation of cork was not observed. It does not take place the first year.

Comparison of Structure of Hypocotyl and Epicotyl.

The hypocotyl has a thicker cortex than the epicotyl: it is without a collenchymatous hypoderma. The endodermis is much more distinct in the former region and the peculiar distribution of starch in the pericycle is more pronounced.

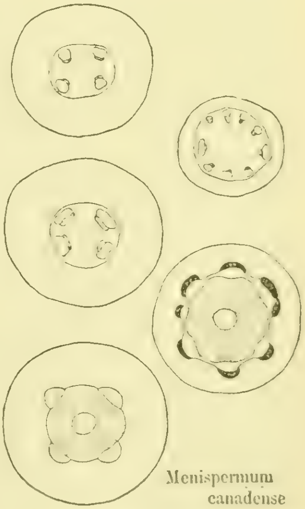


FIG. 6.

Concerning the structure of the stele it is to be noted that in the hypocotyl it is quadrangular; it has but four vascular bundles instead of from eight to twelve and there is no stereom, while in the epicotyl a crescentic mass of stereom borders each phloem bundle.

CALYCANTHACEÆ.

Butneria florida.

Structure of Hypocotyl.

The epidermis consists of cells which are nearly square in cross section. They soon become more or less broken, owing to the early formation of cork. A few short, pointed, unicellular hairs are present.

A true hypoderma becomes differentiated late in the season. About three or four of the sub-epidermal layers of cells become collenchymatous. The cortex has about twenty layers of cells all approximately the same size. Intercellular spaces abound.

The endodermal cells are but slightly smaller than those of the cortex. The endodermis remains more or less distinct until the close of the first year. Starch grains are very small. A few are found in the endodermis, but no starch is present in the other parts of the hypocotyl till late in the season, when it is found in great abundance throughout all the parenchymatous tissues.

The stele is somewhat quadrangular. There are four xylem bundles and four principal phloem bundles. These are situated in the angles of the stele. There are also some small phloem areas. Their location will be seen by reference to the diagram. The phloem and xylem soon form narrow, closed zones. The former is most developed at the original angles of the stele.

It is stated by De Bary [1884], that in the seedlings of Calycanthaceæ a transverse section of the hypocotyl shows six bundles. In the plant under investigation, the present writer found this to be true only for the upper end of the hypocotyl where the cortical bundles, to be mentioned later, are separating and preparing to leave the stele. This appearance is, of course, only seen after the fusion of the primary xylem bundles in pairs, and before complete rings of phloem and xylem are produced.

Toward the upper limit of the hypocotyl there is present a small stereom bundle at each of the four angles of the stele.

These stereom bundles bend outward and accompany the cortical bundles in succeeding internodes.

The pith is rather thick-walled; the cells are about the same size as those of the cortex. A small-celled perimedullary zone of one or two layers is at length clearly distinguishable.

Cork formation begins very early in the outermost sub-epidermal layer of the cells.

Structure of Epicotyl.

The cells of the epidermis when seen in cross section are rectangular with the long diameter parallel to the surface of the section. There are numerous pointed hairs of various lengths.

A collenchymatous hypoderma, four or five layers of cells in thickness, forms the outer part of the cortex, the rest of which is composed of very loose parenchyma.

A definite endodermis was not distinguished. The endodermal region is, however, easily recognized by the presence of starch in many of the cells. Starch is afterward found in great abundance in pith, cortex and medullary rays.

The normal phloem and xylem form closed rings even in the youngest material examined. In the cortex, about half way between the epidermis and phloem are four vascular bundles, ninety degrees apart; each bundle consists of a more or less crescent-shaped mass of lignified sclerenchyma, at whose concave surface is a small area of slightly lignified xylem, consisting usually of five to ten cells. Adjoining this xylem and projecting some distance toward the stele is a lenticular mass of phloem. The general arrangement of the bundle is the same as that carefully described for *Calycanthus* sp. by Woronin [1860] and for *Calycanthus occidentalis* by Williams [1894]. Serial sections showed that in this species these cortical bundles enter the stele about 1 mm. below the insertion of the cotyledons, and not at the middle of the first internode as reported by Herail [1885] for certain other species.

The pith is large. There is a definite perimedullary zone of about three layers of small cells.

The cork cambium is formed very early in the outermost hypodermal layer (cf. Moeller [1882], p. 364).

Comparison of Structure of Hypocotyl and Epicotyl.

The epidermal hairs of the hypocotyl are fewer and shorter than those of the epicotyl. There is in the former region also a less developed hypoderma.

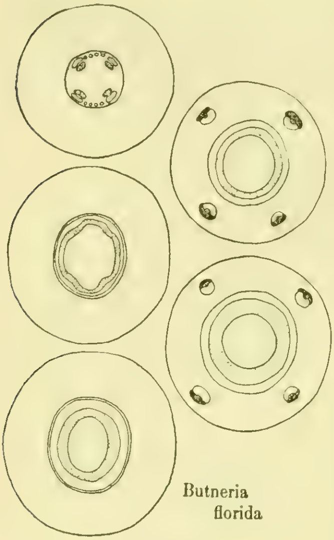


FIG. 7.

The stele of the hypocotyl is originally quadrangular; it is surrounded by a distinct endodermis, and has four xylem bundles and four principal phloem bundles. The stele of the epicotyl is cylindrical, without a distinct endodermis, and even at a very early age, the xylem and phloem form closed rings.

The hypocotyl has no cortical vascular bundles; of these the epicotyl has four.

The presence of true collenchymatous hypoderma in the hypocotyl deserves special mention, as this forms an exception to the general rule that collenchyma is not developed in the hypocotyl.

CÆSALPINACEÆ.

Parkinsonia aculeata.

Structure of Hypocotyl.

The epidermis is composed of cells which are rectangular in cross section. They are, at first, radially elongated. Eventually they become elongated in the other direction.

The cortex is many-layered. There is no hypoderma. The outer cells of the cortex are much smaller than those further down. Very early in the history of the hypocotyl a parenchymatous sheath of small cells is formed in the cortex about midway between epidermis and endodermis. The cells are not arranged in definite rows. The position of this sheath is shown in the last plate accompanying this paper.

The cells of the endodermis are smaller than those of the cortex. They contain starch. The endodermis is quite distinct; it was, however, not definitely distinguished in material collected late in the season. The cortex and pith at a later time also have some starch.

The stele is four-angled. There are originally four phloem bundles and eight paired xylem bundles. Eventually closed rings of xylem and phloem are formed.

At the corners of the stele in the pericycle groups of sclerenchyma are formed. The cells become very thick-walled and each group quite large.

The pith is large. The cells are rather thick-walled. No definite perimedullary zone was distinguished.

In the material examined cork formation had not commenced.

Structure of Epicotyl.

The epidermal cells are thin-walled, square in cross section, becoming at length much flattened. There is no collenchyma. The cortex is narrow; the cells are about the same size as those of the epidermis.

The endodermis is composed of thin-walled cells. After secondary growth of the stelar tissues it cannot be definitely seen. The cells are about the same size as those of the cortex; they contain starch. Starch is found at a later time in the various parenchymatous tissues.

The number of vascular bundles is variable. Usually there are about twelve. These, at length, fuse to form closed rings of phloem and xylem.

The pericycle develops a sheath of sclerenchyma which almost completely shuts in the phloem. The cells were not very thick-walled in the material examined.

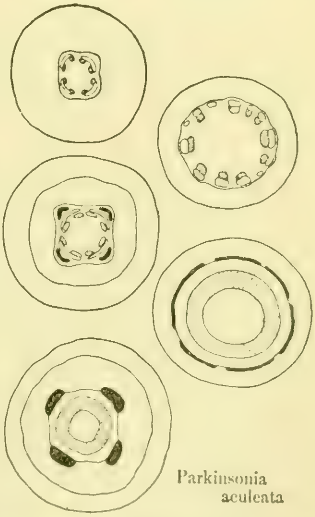
The pith is large, the cells rather thin-walled. A perimedullary zone of small-celled parenchyma at length becomes differentiated.

No material old enough to show cork formation was examined.

Comparison of Structure of Hypocotyl and Epicotyl.

The hypocotyl differs from the epicotyl in having a thicker cortex with a narrow small-celled parenchymatous sheath. The cells of the cortex are also larger.

In its primary stelar structure the differences are very marked. The



Parkinsonia aculeata

FIG. 8.

hypocotyl has four phloem bundles and eight xylem bundles instead of a large number of conjoint bundles. It has four large groups of stereom instead of a narrow, almost continuous sclerenchymatous sheath.

Cercis canadensis.

Structure of Hypocotyl.

The epidermal cells are rectangular in cross section; the radial diameter is the longer. These cells never become tangentially elongated. The cells of the outer cortex are smaller than those within. An indefinite sheath of small-celled parenchyma similar to that in *Parkinsonia* can sometimes be recognized.

The endodermis is small-celled; it remains distinct through the first year. Its cells contain starch. Starch is also present toward the close of the year in the pith.

The stele is originally quadrangular. There are four xylem bundles and four phloem bundles. These, at length, develop into closed rings.

Four small groups of sclerenchyma make their appearance in the pericycle at an early time and become, at length, considerably extended.

The pith finally becomes cylindrical. The cells are large and thin-walled. The perimedullary zone is not clearly differentiated.

Cork formation takes place in the cortex either next to or very near the endodermis. It begins sometime before the close of the season.

Structure of Epicotyl.

The epicotyl is somewhat quadrangular in the early stages. The epidermal cells are rectangular in cross section. The tangential diameter is the greater. There is no hypoderma. The cortex is thin. The cells are all about the same size.

The endodermis was not definitely distinguished. In the youngest material examined the phloem forms a closed ring. There are four large primary xylem bundles. There are also some smaller ones. The latter have often only one or two xylem cells. A closed zone of xylem is soon produced.

Nearly all the cells of the pericycle become, at length, sclerotic, thus forming an almost continuous sheath with but few parenchymatous cells.

The pith is large-celled. A perimedullary zone was not distinguished.

Cork formation takes place in the second cortical layer as in *Cercis siliquastrum* (fide Moeller [1882]).

Comparison of Structure of Hypocotyl and Epicotyl.

The epidermal cells of the hypocotyl, when seen in cross section, appear radially, not tangentially elongated as in the epicotyl. In the former region the endodermis is distinct, the cortex thicker and the sclerenchyma at first differently disposed.

The stele of the hypocotyl has originally four phloem bundles and four xylem bundles. The youngest material of the epicotyl which was examined has a closed ring of phloem and four large xylem bundles, also a few small groups of xylem.

Cork formation in the hypocotyl takes place in the lower cortex; in the epicotyl it takes place in the second cell layer of the cortex.

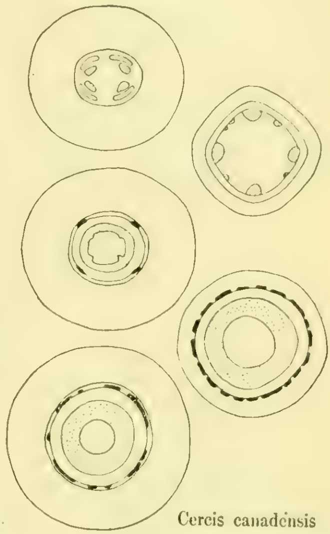


FIG. 9.

Gleditsia triacanthos.

Structure of Hypocotyl.

The epidermis is composed of rather thick-walled cells which are oblong in cross section, the long axis being at right angles to the periphery of the section. These cells are eventually elongated in the tangential direction.

The cortex is very thick. There is no differentiated hypoderma, but three or four of the outer cortical layers are composed of smaller cells than those below.

The endodermis is definite; it is large-celled. In some places it is two layers of cells in thickness. Starch, at first present only in the endodermis, is eventually widely distributed throughout all the parenchymatous tissues.

The stele is cylindrical. There are in the young hypocotyl eight paired xylem bundles and a large number of groups of phloem. The latter soon grow together, forming a complete ring, while the xylem bundles first fuse in pairs, afterward growing together into a closed zone.

In the pericycle, alternating with the paired xylem bundles there are developed four large bands of sclerenchyma which extend so far around that they nearly touch each other. By the end of the first season these become divided into a number of groups by the intercalation of parenchymatous cells.

The pith, which is eventually of slight extent, is composed of large-celled parenchyma.

Cork formation begins rather early the first season in the third or fourth cell layer of the cortex.

Structure of Epicotyl.

The general shape of the epicotyl is originally somewhat hexagonally prismatic; it soon becomes cylindrical.

The cells of the epidermis are originally nearly square in cross section. There are numerous, long, curved, pointed epidermal hairs. The outer two layers of the cortex become slightly collenchymatous. The other cortical layers are composed of parenchyma.

The endodermis was not distinguished in material taken in the autumn but in the young epicotyl is quite distinct. The cells are rather large, similar to those of the cortical region but packed with starch.

The phloem, in youngest material examined, forms a ring of tissue. There are about six principal xylem bundles which soon fuse.

A broken sclerenchymatous ring is formed which resembles that of the epicotyl. No other stereom is, as a rule, produced the first year.

The pith is large and composed of cells with unlignified walls. There is a small-celled perimedullary zone.

Cork formation takes place in the hypoderma (cf. Moeller [1882], p. 393).

Comparison of Structure of Hypocotyl and Epicotyl.

The hypocotyl differs from the epicotyl in the absence of epidermal hairs and of a collenchymatous hypoderma, in the primary structure of the stele, and in its smaller pith.

In the hypocotyl there are at first four pairs of xylem bundles and a number of phloem bundles. Four large groups of sclerenchyma soon make their appearance in the pericycle. In the epicotyl, on the other hand, a closed ring of phloem surrounds usually about six xylem bundles. No differentiated perimedullary zone was distinguished in the hypocotyl.

The structure of the two regions at the close of the first year differs only in the perimedullary region and pith; the formation of cork having removed the epidermis and hypoderma.

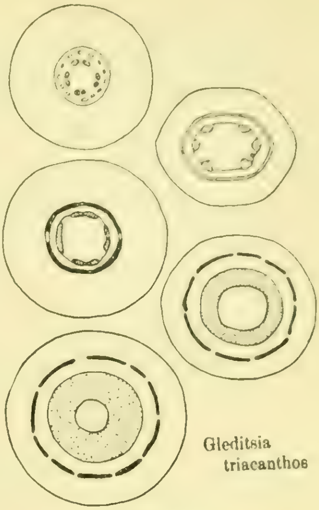


FIG. 10.

PAPILIONACEÆ.

Amorpha fruticosa.

Structure of Hypocotyl.

The epidermis consists of cells rather small, somewhat thick-walled, square or nearly so, in cross section, at length becoming flattened. The cells of the cortex are large; those immediately below the epidermis somewhat smaller, but not forming a definite hypoderma.

The endodermis of thin-walled cells containing starch remains distinct for some time. Toward the close of the first year its exact position cannot be determined, although it can be located approximately. A small amount of starch is scattered throughout the cortex, pith and pericycle as well as the endodermis, even in the youngest stage. This is not the case in most species. Later the phloem and the medullary rays also come to be filled with starch.

The stele is at first quadrangular, and remains so for a considerable length of time. There are four conjoint vascular bundles, and in addition there appear a few small patches of phloem. The bundles soon tend to unite in pairs. Xylem and phloem at length form complete zones. The medullary rays are very numerous; they are one cell in width.

About the time that the epicotyl has reached its full length four small areas of sclerenchyma appear in the pericycle, one adjoining the phloem of each vascular bundle. These increase somewhat in size, and are still visible in two-year-old material. Numerous isolated sclerenchymatous elements are found scattered through the phloem.

The pith is composed of rather large cells with thin walls, which soon become lignified. As the plant grows older the pith becomes almost obliterated. No perimedullary zone was distinguished.

Cork formation takes place in the outer pericycle, at length cutting off all tissues outside, leaving the bundles of sclerenchyma which are at the inner limit of the pericycle.

Structure of Epicotyl.

The epidermis is composed of cells nearly square in cross section. These abut directly upon a large-celled, few-layered cortex. There is no hypoderma.

A definite endodermis was not distinguished at any time although in a very young stage certain starch containing cells were recognized as having the appearance of endodermis; a continuous ring of them was not traced. With the exception of the endodermal and medullary region, starch does not occur until the plant has developed a number of internodes above the epicotyl. The cells of pericycle and phloem are at length filled with starch.

The stele is cylindrical from the first. Owing to fusions the number of vascular bundles is variable. There are, however, generally about five or six bundles. The phloem and xylem eventually form closed rings.

There is a narrow interrupted ring of stereom at the outer edge of the pericycle. Toward the end of the first season numerous small patches of thick-walled fibers appear in the phloem and the pericycle.

The pith is large-celled; it does not decrease appreciably in size as the stem grows older.

In the lower part of the epicotyl cork formation takes place in the pericycle below the ring of stereom mentioned above, thus cutting off the cortex and epidermis which soon die and disappear. In the upper part it takes place in the cortex (cf. Moeller [1882], p. 383). This plant shows a distinct "region tigellaire" in two-year-old material.

Comparison of Structure of Hypocotyl and Epicotyl.

In very young plants the hypocotyl shows a few slightly differentiated layers of smaller cells in the outer cortex. The epicotyl has nothing of the kind.

The endodermis of the hypocotyl is distinct in the early stages, but was not definitely located in the epicotyl. Starch appears earlier in the hypocotyl and the four large groups of stereom are not represented at all in the epicotyl which, however, has an interrupted circle of the same material.

In the former region the stele is at first quadrangular, while always cylindrical in the latter. Cork formation in the hypocotyl is pericyclic, but is cortical in the epicotyl.

The final structure of the two regions is very similar, save in the arrangement of sclerenchyma.

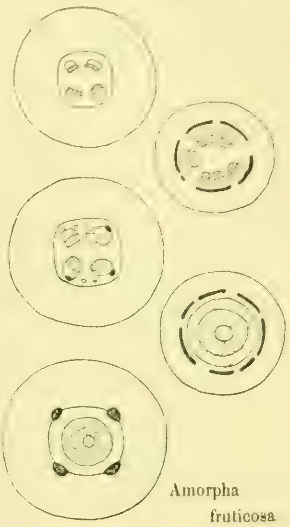

Amorpha fruticosa

FIG. II.

Robinia pseudacacia.

Structure of Hypocotyl.

The epidermal cells are oblong in cross section, radially elongated at first, later becoming elongated in the tangential direction. A few straight multicellular hairs are present. There is no differentiated hypoderma. The cells of the cortex are all about the same size.

The endodermis is small-celled and contains starch. It is not easily distinguished in material taken at the close of the growing season. Starch is also found in some of the pericyclic cells in early stages. Later nearly all the parenchymatous tissues have starch.

The stele is originally quadrangular. There are eight phloem bundles and four xylem bundles. These soon produce closed zones.

In the pericycle opposite each of the original xylem bundles a group of stereom appears. These groups, at length, become quite large. In addition to these, at the close of the first year, there are some small patches of stereom irregularly disposed just outside the phloem.

The pith is composed of parenchymatous cells which acquire thick lignified walls. There is a well-differentiated perimedullary zone three or four cells in width. The cells are small and have thick lignified walls.

Cork formation, according to Flot [1890], takes place rather deep in the cortex.

Structure of Epicotyl.

The cells of the epidermis are square or oblong in cross section, and become in time greatly flattened. There are numerous epidermal hairs. A narrow collenchymatous hypoderma is present. The cells of the cortex are about the same size as the epidermal cells.

The endodermis was distinguished only in very young stages. The cells are rather small and closely packed with starch. Starch is found at a later time in the various parenchymatous tissues. Troschel [1879] states that in year-old twigs starch is present in some of the elements of the wood but disappears the next year.

In young material the epicotyl is elliptical in cross section. The stele follows this closely in shape. The phloem forms a closed ring surrounding a variable number of xylem bundles. There are usually more than eight of these bundles. The xylem also soon forms a complete zone in which medullary rays are prominent.

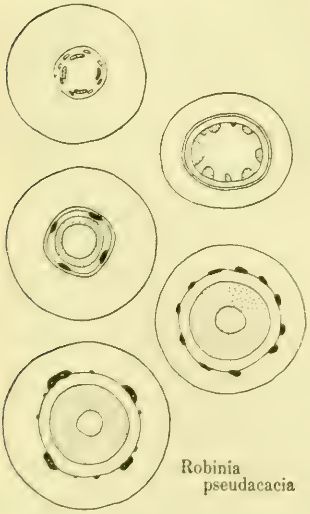


FIG. 12.

The pith cells become, at length, thick-walled. There is a well-defined perimedullary zone.

Cork arises in the fourth, fifth or sixth layer of the cortex (cf. Moeller [1882], p. 384).

Comparison of Structure of Hypocotyl and Epicotyl.

The hypocotyl is without the collenchymatous hypoderma of the epicotyl; it has fewer epidermal hairs; the cortex is thicker; there are four large groups of stereom with some very small ones instead of a broken ring of medium-sized bundles.

In its primary structure the stele of the hypocotyl differs considerably from that of the epicotyl. There are four xylem bundles instead of eight or more and eight phloem bundles instead of a closed ring of phloem.

The cork, although of cortical origin in both regions, arises in the hypocotyl in deeper layers.

RUTACEÆ.

Ptelea trifoliata.

Structure of Hypocotyl.

The cells of the epidermis, when seen in cross section, appear nearly square. They, at length, are flattened. There are a few short, blunt, unicellular hairs. The cortex is large-celled. There is no distinct hypoderma differentiated.

The endodermis is large-celled and contains, at first, very little starch. It later becomes closely packed with starch. The various parenchymatous tissues at length also contain starch in the cell cavities. Numerous lysigenous reservoirs are present in the outer part of the primary cortex.

The stele is originally four-angled. There is one phloem bundle and one xylem bundle in each angle. The phloem soon forms a closed ring surrounding the now greatly enlarged xylem bundles which enclose, at this stage, a somewhat cruciform pith. The xylem bundles also finally fuse.

Four very small groups of sclerenchyma appear, toward the end of the season, in the pericycle. They are equidistant. There are about six cells in each group. Some sections do not show all these groups, as the sclerenchymatous elements do not form continuous strands in the hypocotyl. Some sections show no sclerenchyma at all.

The pith is eventually quite small. The perimedullary zone is not well developed.

The formation of cork begins early in the outermost cortical layer of cells.

Structure of Epicotyl.

The epidermis is composed of cells which appear slightly rectangular in cross section. They are elongated in the tangential direction. Numerous epidermal hairs are present. There is a narrow collenchymatous hypoderma. The cells of the inner cortex are very large.

The endodermis is distinct and can be recognized in year-old material. Starch is present from the first. The various parenchymatous tissues at length have a small amount of starch. Secretion cavities develop in the cortex.

The stele is small; much smaller than is usual in most species. In the youngest material examined the phloem forms a complete ring surrounding a small number of xylem bundles which eventually fuse.

Numerous groups of elements in the pericycle become sclerotic so that they form an interrupted ring of sclerenchyma surrounding the phloem.

The pith is small, unusually so for an epicotyl. There is a definite perimedullary zone of small-celled parenchyma containing starch.

The formation of cork takes place in the outermost layer of hypoderma (cf. Moeller [1882], p. 326).

Comparison of Structure of Hypocotyl and Epicotyl.

The hypocotyl does not have the epidermal hairs and the collenchymatous hypoderma of the epicotyl. The cortex of the former region, though very thick, is but little thicker, in proportion, than that of the epicotyl.

In the stele of the hypocotyl there are four phloem bundles and an equal number of xylem bundles, while in the epicotyl, in the youngest material examined, the phloem forms a closed ring surrounding about six xylem strands.

The sclerenchyma of the hypocotyl is in four somewhat irregular columns in the pericycle, while in the epicotyl it forms more nearly a closed sheath. In the former region also the perimedullary zone is poorly developed.

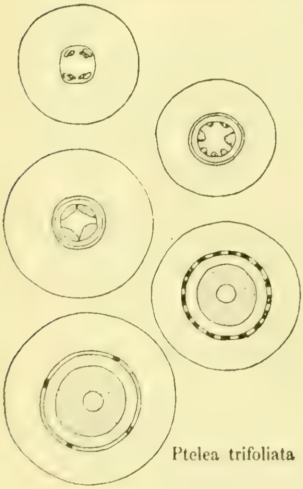


FIG. 13.

SIMARUBACEÆ.

Ailanthus glandulosa.

Structure of Hypocotyl.

The epidermis consists of small cells, square or nearly so, in cross section, and considerably bulged when young. A few short, unicellular hairs were seen, but none noted in very young plants. There is a hypoderma of one or two layers of somewhat larger and thicker-walled cells. The rest of the cortex is parenchymatous and large-celled.

The endodermis consists of cells somewhat smaller than those of the adjacent cortical layer. The endodermis was not recognized in older material. Starch is present from the first in the endodermis, pericycle and pith, but does not appear in the cortex till nearly the close of the first season.

The stele is at first quite small. There are four xylem bundles arranged in pairs and four phloem bundles similarly disposed. The phloem soon forms a complete ring, surrounding the now considerably enlarged xylem bundles, which also eventually form a closed ring.

Opposite each of the four original xylem bundles there appears in the pericycle a group of sclerenchymatous cells. These groups become, at length, somewhat divided so that the old hypocotyl may have a considerable number of smaller groups. There are numerous sclerenchymatous fibers scattered in small and large patches through the phloem and pericycle.

The pith is thin-walled; toward the end of the first season it becomes lignified. The perimedullary zone, described by Flot [1893], as an important feature of the stem structure is first definitely noted at this time.

The oleoresin canals described by Trécul [1867] as occurring at the outer border of the pith, and by Van Tieghem [1884] as in the inner xylem of the stem, were not distinguished in the hypocotyl. Crystal rosettes of calcium oxalate occur singly in certain cells of the phloem area. Single oleoresin cells are found here and there in the cortex and phloem.

Cork formation, as noted by Flot [1889 and 1890] takes place in the layer of cells just below the epidermis.

Structure of Epicotyl.

The epidermis resembles that of the hypocotyl, but there are numerous, somewhat long, curved or hooked epidermal hairs. Most of these are unicellular.

The hypoderma is, as previously described for the stem by De Bary ([1884], p. 404), collenchymatous. The cells are small; toward the inside the hypoderma gradually shades into the ordinary cortex.

A definite endodermis was not distinguished at any stage, although, since starch is present in the region of the pericyle and endodermis from the first, those regions can be located approximately. Starch is found later in pith and cortex; also in many of the inner xylem elements.

There are, at first, eight to ten conjoint vascular bundles. Eventually the phloem and xylem form closed rings.

Scattered sclerenchymatous elements are found in the phloem, pericycle and cortex.

The pith is irregular in outline. The first formed xylem elements project into it. The perimedullary zone is not conspicuous the first year, being composed of a few cells with unlignified walls.

The cork cambium is formed in the outermost hypodermal layer (cf. Moeller [1882], p. 327).

Comparison of Structure of Hypocotyl and Epicotyl.

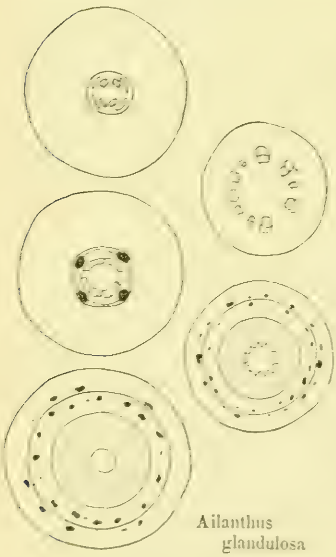


FIG. 14.

The hypocotyl has a few, the epicotyl a considerable number, of epidermal hairs. The hypocotyl does not have the collenchymatous hypoderma found in the epicotyl. The pith is smaller and circular instead of scalloped; the perimedullary zone is better developed.

The endodermis is distinct in the hypocotyl for a considerable time, while in the epicotyl it was not definitely distinguished at all. The hypocotyl has, at first, four xylem and four phloem bundles; the epicotyl eight to ten conjoint bundles.

At the close of the year the only differences are those noted in the medullary and perimedullary regions.

ANACARDIACEÆ.

Schinus molle.

Structure of Hypocotyl.

The epidermal cells are square or oblong in cross section, becoming, at length, flattened. There are numerous short epidermal hairs. No hypoderma is developed but the cells of three or four outer layers of the cortex are smaller than those of deeper layers.

The endodermis is small-celled and easily recognized in young stages, although at that time the cells are without starch. Later starch appears in small quantities in these cells and in those of the pith and phloem.

The stele is originally four-angled and remains so for some time. In each angle there is a single xylem bundle and two groups of phloem; these form a crescent-shaped mass bordering a group of cells which later develop into a resin duct. After a time secondary vascular bundles are intercalated between the primary bundles. All finally fuse to produce closed zones of phloem and xylem.

A few small groups of sclerenchymatous cells develop at the outer border of the phloem.

The pith remains somewhat four-sided. The four original xylem bundles project into it at the angles. The pith cells have thin, unlignified walls. A perimedullary zone of small cells was distinguished.

Material old enough to show cork formation was not obtained.

Structure of Epicotyl.

The epidermis resembles that of the hypocotyl. Trichome structures seem to be no more abundant. There is no collenchymatous hypoderma developed. The cells of the cortex are all about the same size.

The endodermis is not easily recognized owing to the fact that in young stages it contains no starch. Later when starch is present the cells have been compressed and displaced by pressure from the subjacent tissues.

The stele contains a variable number of vascular bundles. Usually there are about eight. In connection with each bundle is a small resin passage, at first pointed out by Trécul [1867]. In older material these resin passages become quite large and somewhat flattened. The phloem and xylem then form closed zones.

Groups of sclerenchyma, usually consisting of only a few cells, are found at the periphery of the phloem. These are often located near the resin passages.

The pith is nearly circular, not quadrangular, and is composed of large, thin-walled cells. There is a distinct perimedullary zone.

The region of cork formation was not determined.

Comparison of Structure of Hypocotyl and Epicotyl.

In their primary structure the steles of the hypocotyl and epicotyl show important differences. That of the former region is quadrangular; it has four primary vascular bundles and at a later time other secondary bundles are intercalated. These latter do not have resin canals. In the epicotyl there are about eight vascular bundles each with a resin canal.

The pith of the hypocotyl is four-sided, that of the epicotyl circular in outline, when seen in cross section.

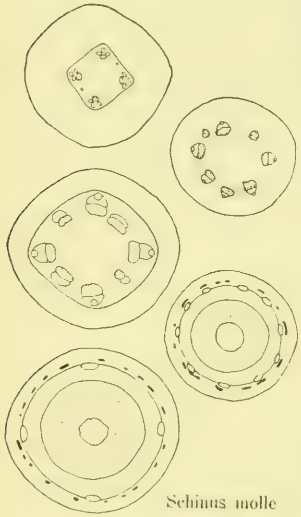


FIG. 15.

RHAMNACEÆ.

Berchemia racemosa.

Structure of Hypocotyl.

The cells of the epidermis are nearly square in cross section, sometimes radially elongated, but becoming at length considerably flattened. No hypoderma is developed, although the cells of the outermost layer of cortical tissue are considerably smaller than those below. There are about five layers of cells in the cortex. This tissue is extremely loose, having many intercellular spaces.

The endodermis is quite distinct until nearly the time that cork formation begins. The cells are smaller than those of the cortex but larger than the pericyclic elements.

Starch is present in the endodermis from the first, but does not appear in the cortex at all, nor in the pith and phloem till about the close of the season.

The stele is originally four-angled. There are four xylem and four phloem bundles. These are paired. They soon fuse so that there are two crescent-shaped bundles, and by further growth closed rings of xylem and phloem are produced.

While the bundles are in the crescent form four small groups of sclerenchyma appear in the pericycle, one opposite each of the original xylem groups.

The pith is composed of large cells, whose thin walls become, at length, somewhat lignified. A perimedullary zone of about two layers may be distinguished but is not always continuous the whole way around the pith.

The cork has its origin in the inner cortex or in the endodermis. Some of the layers of cork carry a brown pigment.

Structure of Epicotyl.

The epidermis, composed originally of small cells, square or pentagonal in cross section, eventually becomes strongly cuticularized and the separate elements very much flattened.

There is no hypoderma developed. The cortex is rather large-celled, but very narrow, being only three or four layers of cells in thickness. During the second year the walls of these cells become conspicuously pitted. Many large crystals, chiefly cubical in form, are found in this region.

The endodermis, composed of flat cells containing starch is distinct till near the close of the first season. Except in the endodermis starch is absent until about the end of the first year's growth, when it appears in the pith and medullary rays.

Even in very young stages the phloem forms a closed zone surrounding a ring of from six to ten, but generally about eight, xylem bundles. These soon become fused. A narrow band of sclerenchyma, for the most part only one cell wide, is found at the outer limit of the phloem; it does not form a closed ring, but is more or less irregular and broken. Small patches of sclerenchyma are found in the phloem of two-year-old seedlings.

The pith is large-celled; the walls are thin but slightly lignified. No perimedullary zone was distinguished.

The region of cork formation was not distinguished. Two-year-old material was examined, but the cork cambium had not begun to form.

Comparison of the Structure of Hypocotyl and Epicotyl.

The epidermis of the hypocotyl remains thinner-walled and exhibits less cuticularization than that of the epicotyl. This is to be expected, since in the former region cork is produced the first year, while in the latter not till a later period.

The hypocotyl has at first four xylem and four phloem bundles, the epicotyl a closed ring of phloem and about eight xylem bundles. In the former area there are but four groups of sclerenchyma, while in the latter there is an interrupted circle of thick-walled elements just outside the phloem.

The pith of the hypocotyl is smaller than that of the epicotyl.

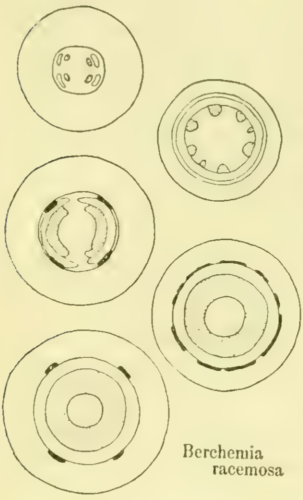


FIG. 16.

Rhamnus purshiana.

Structure of Hypocotyl.

The cells of the epidermis are originally square or pentagonal in cross section. They become, at length, much flattened. The cortex is thick and very large-celled. No hypoderma is differentiated.

The endodermis consists of small, thin-walled cells containing starch. It remains distinct until cork formation takes place. Starch is found, late in the season, in the perimedullary zone and phloem, but not in the cortex.

The stele is originally somewhat four sided and has four vascular bundles which soon fuse and produce closed zones.

The pith is composed of very large cells. The perimedullary zone is rather ill-defined. It is one or two cells in width. The cells are small and contain starch.

The cork is of endodermal origin. Its formation begins toward the close of the growing season.

Structure of Epicotyl.

The epidermal cells, at first square or pentagonal in cross section, become at length, considerably flattened. There are numerous short, curved and pointed hairs. A poorly developed hypoderma is present in year-old material. The cells of the cortex are all about the same size.

The endodermis was distinguished only in young material. The cells are small and contain starch. The perimedullary zone, cortex and phloem have at a later time, small amounts of starch.

The phloem, in the youngest material examined, forms a complete ring. There are about six xylem bundles. These soon fuse.

Considerable masses of stereom develop at the periphery of the phloem forming a broken sheath.

The pith is large-celled. There is present a definite perimedullary zone of small cells containing starch. The cell walls are lignified.

Cork is produced in the outermost hypodermal layer as in other species of *Rhamnus* (cf. Moeller [1882], pp. 292 et seq.).

Comparison of Structure of Hypocotyl and Epicotyl.

The hypocotyl has a thicker cortex than the epicotyl; it does not have a hypoderma; epidermal hairs are absent; the sclerenchymatous ring found in the epicotyl is here absent.

The endodermis of the hypocotyl remains distinct for a greater time than that of the epicotyl. The former region has originally four vascular bundles; the latter has, in the youngest material examined, a zone of phloem and about six xylem bundles. Cork formation in the hypocotyl is endodermal while in the epicotyl it is hypodermal.

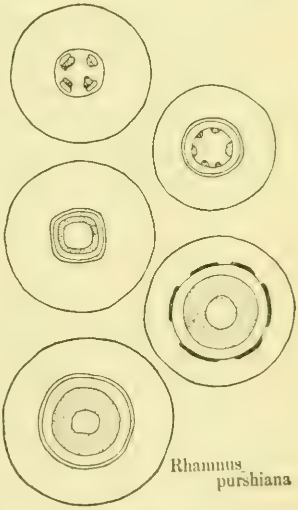


FIG. 17.

VITACEÆ.

Vitis cordifolia.

Structure of Hypocotyl.

The cells of the epidermis are nearly square in cross section, but become at length considerably flattened. Many of them are somewhat prolonged, forming short, blunt papillæ. A thick cuticle is present. In cross section it appears minutely notched.

Three or four of the outer layers of the cortex are small-celled, but not collenchymatous. The cells of deeper layers are larger and all about the same size.

The endodermis is small-celled, and is for a long time readily distinguished because it contains starch. Starch is generally absent from the other tissues, but, at a later time, appears in the pith.

There are four primary vascular bundles. Other secondary bundles soon become intercalated and finally complete rings of phloem and xylem are produced.

A single group of sclerenchymatous elements is formed at the outer edge of each primary vascular bundle. By the end of the season other smaller groups are also present.

The pith finally becomes very small. Sometimes, by the projection into it of two of the vascular bundles, a line of xylem extends nearly across it. There is no perimedullary zone.

The cork cambium, as in other species of *Vitis* (cf. Flot [1889]), is formed about the close of the first season in the pericycle.

Structure of Epicotyl.

The epidermal cells are square in cross section, becoming at length flattened. The cuticle is like that of the hypocotyl. A well-differentiated collenchymatous hypoderma is present. The other cells of the cortex are parenchymatous.

The endodermis contains starch and is, therefore, easily distinguished. Toward the end of the season starch is also found in the pith. The number of primary vascular bundles is variable. Usually there are more than eight. At an early time closed zones of phloem and xylem are produced.

A broken ring of sclerenchyma is developed toward the end of the first year in the pericycle.

The pith is thin-walled and large-celled. A definite perimedullary zone was not distinguished.

The cork, as in the hypocotyl, is of pericyclic origin (cf. Moeller [1882], p. 207).

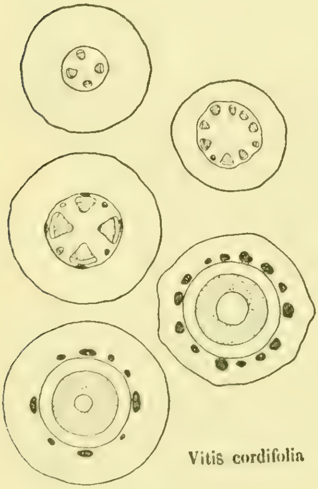


Fig. 18.

Comparison of Structure of Hypocotyl and Epicotyl.

The hypocotyl has a thicker cortex than has the epicotyl. It has but four primary vascular bundles instead of eight or more. It has four large masses of sclerenchyma in the pericycle and a few smaller ones instead of a more nearly continuous sclerenchymatous ring.

The pith of the hypocotyl becomes, at length, nearly obliterated.

ELÆAGNACEÆ.

Elæagnus umbellata.

Structure of Hypocotyl.

The cells of the epidermis are more or less oblong in cross section. There are no epidermal hairs. The outermost layer of the cortex becomes somewhat thick-walled but not collenchymatous. The cortex has about six cell rows.

The endodermis is small-celled. It remains distinct for a time, but in sections of material gathered at the end of the season it was not distinguished. Very little starch is found in any of the tissues save in the endodermis.

The stele is originally four-angled. A single phloem bundle and two xylem bundles are placed in each of the angles. The phloem soon forms a closed ring while the xylem bundles fuse in pairs and increase in size. This leaves a cruciform pith. The continued growth of the xylem produces a complete zone surrounding, at length, a circular pith. Secretion cells in the phloem are numerous.

At the outer edge of the xylem, in old material, are a few patches of sclerenchyma forming a very much interrupted ring.

The pith is of considerable extent and is surrounded by a perimedullary zone of small cells containing starch.

Cork formation takes place far down in the cortex.

Structure of Epicotyl.

The epidermis consists of cells which are oblong in cross section with the tangential about twice the radial diameter even in very young material. The peculiar stellate trichome structures, well known in this genus, are abundant.

The outer cortical cells are nearly circular in outline, when seen in cross section. They are somewhat smaller than the cells of the epidermis. The inner cortex is composed of large cells which eventually are very much flattened owing to pressure of the growing parts within.

The endodermis is small-celled and contains starch. In old material it was not recognized.

The stele is circular from the first. In the youngest material examined the phloem forms a complete ring surrounding about six xylem groups. The xylem bundles soon fuse producing at the end of the season quite a thick zone.

An interrupted sclerenchymatous ring is developed in the pericycle.

The pith, which is composed of large thin-walled elements, is surrounded by a narrow small-celled perimedullary zone containing starch.

The cork is formed rather late in the season in the outermost cortical layer as in other species of *Elaeagnus* (cf. Moeller [1882], p. 117).

Comparison of Structure of Hypocotyl and Epicotyl.

The hypocotyl is without the trichome structures so noticeable in the epicotyl; the stele is at first four-angled instead of cylindrical; there are four phloem bundles and eight xylem bundles instead of a ring of phloem and six xylem bundles.

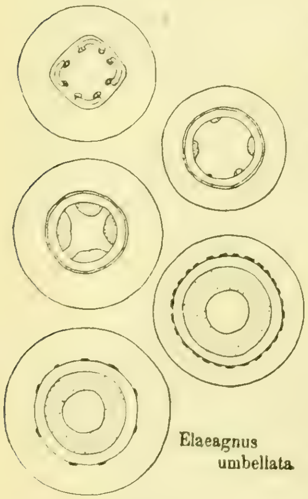


Fig. 19.

At the end of the season the vascular tissue is alike in the two regions but the pericyclic sclerenchyma of the hypocotyl is less abundant. Cork is developed in the inner cortex of the hypocotyl and in the outermost layer of cortex in the epicotyl.

MYRTACEÆ.

Eucalyptus globulus.

Structure of Hypocotyl.

The epidermal cells, at first oblong, radially elongated, become at length in cross section nearly square. The cuticle, which is covered with elevations, appears, when young, in cross section minutely serrate.

There is no hypoderma differentiated, but the outermost layer of the cortex is smaller-celled than the layers below. The cortical cells are large. They become flattened toward the end of the season by the growth of the internal tissues.

The endodermis is composed of small cells containing starch; it at length becomes indistinguishable. Starch is for the most part absent from other tissues. Lysigenous secretion reservoirs are found in the conjunctive tissue.

The stele is four-sided. The general shape of the hypocotyl sometimes follows that of the stele (cf. Irmisch [1876]). There are originally four narrow curved phloem bundles and the same number of small xylem bundles. The phloem soon forms a closed ring; the xylem bundles increase in size, leaving for a time a cruciform pith; but eventually the xylem also forms a complete ring and the pith is cylindrical.

Four small groups of sclerotic cells make their appearance in the pericycle about the time that the phloem ring is first formed. These groups eventually become somewhat broken up and numerous groups of fibers appear in the phloem arranged in three or more interrupted circles.

The pith is large-celled. It is small in amount even from the first. No definite perimedullary zone was distinguished.

Cork formation, according to Flot [1890], is cortical or pericyclic.

Structure of Epicotyl.

The cells of the epidermis are at first more nearly square in cross section than those of the hypocotyl. They at length become very much elongated in a tangential direction.

The cortex is large-celled; the cells of the outer layer are rather small. No hypoderma is differentiated. Numerous lysigenous secretion sacs are present.

The endodermis is thin-walled; the cells are small and contain starch.

The stele is at first somewhat quadrangular and becomes at length elliptical, in cross section. In the youngest material examined the phloem forms a closed ring. The number of xylem bundles is somewhat variable; these are so disposed that the pith is generally at first somewhat cruciform.

The pericycle becomes, at length, largely sclerenchymatous; numerous interrupted rings of bast fibers begin to appear but are only slightly thickened the first year.

The pith, at first cruciform, becomes somewhat quadrangular. There is a perimedullary zone (*fide* Flot [1893]). An internal cambium produces a ring of phloem just outside the pith: This is mentioned by DeBary [1884]. A few sclerotic cells were noted at the inner limit of the internal phloem.

According to Flot [1890] cork formation is sub-epidermal.

Comparison of Structure of Hypocotyl and Epicotyl.

The hypocotyl is more nearly cylindrical than the epicotyl; its epidermis less flat, its stereom is better developed the first year. Stem internodes above the epicotyl are square.

The primary structure of the hypocotyl is like that of *Tecoma*. There are four xylem bundles and four phloem bundles. In the youngest epicotyl examined the phloem forms a complete ring and there is a variable number of xylem bundles.

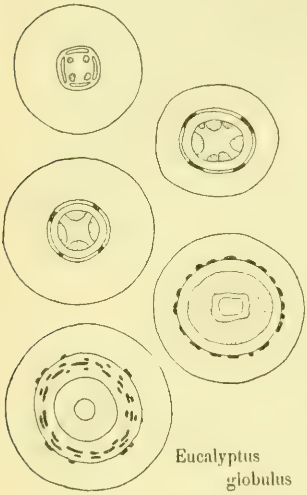


Fig. 20.

No internal phloem was recognized in the hypocotyl although it is quite distinct in the epicotyl. The cork of the former region is pericyclic or cortical in origin, that of the latter subepidermal.

BIGNONIACEÆ.

Tecoma radicans.

Structure of Hypocotyl.

The epidermal cells are rectangular in outline when seen in cross section. From being originally radially elongated they are, at length, nearly square. The cuticle in cross section appears minutely serrate. There are a few short, simple, epidermal hairs.

The cortex is of loose parenchyma, generally about six layers in thickness. There is no differentiated hypoderma.

The endodermal cells are smaller than the cells of the cortex. Originally they are irregularly hexagonal in outline, but toward the end of the year they become elliptical and have slightly thickened walls. Starch is entirely absent, except in the endodermal region until nearly the close of the first year, when it appears especially in the pith.

The stele is originally very small and somewhat four-sided, containing four xylem bundles and four phloem bundles. The latter are next the pericycle. They alternate with the xylem bundles. These are presumably the four "principal bundles" found, according to Hovelacque [1888], in all Bignoniaceous stems. At quite an early stage the phloem and xylem form closed rings.

About the time that this is apparent four small groups of sclerenchyma make their appearance in the pericycle just outside the original xylem bundles. Each of these is composed of only six to ten cells with extremely thick walls. Later numerous isolated, lignified sclerenchymatous cells appear in the outermost layer of the cortex; a few also are found in the phloem area.

The pith is large-celled and thin-walled. The formation of a cambium layer in the small-celled perimedullary region begins some time before the close of the year. This will be further noticed in the description of the epicotyl.

Cork formation takes place in the second cortical layer, *i. e.*, in the cell layer immediately below the sclerenchyma which is thus eventually lost.

Structure of Epicotyl.

The epidermis has a well-marked cuticle which, in cross section, appears minutely notched. The cells seen in cross section are about square, but become tangentially elongated toward the end of the season. There are occasional short epidermal hairs.

The cells of the outermost layer of the cortex are somewhat smaller than those of deeper layers. These are considerably flattened. Although at first of about even thickness throughout, the cortex soon grows in thickness at four equidistant points giving the epicotyl a quadrangular prismatic shape.

The endodermis, which in young stages is distinct, at length becomes indistinguishable owing to displacement and crowding of the cells caused by growth in the lower layers. Starch, though present in the endodermal region, is found only in very small amount in the cortex and pith until the close of the season. Even then the cells are not closely packed with it.

Even in the youngest stage examined, *i. e.*, second stage of our arbitrary division, the phloem and xylem form complete rings.

The outermost cortical layer toward the end of the season becomes largely sclerenchymatous, although here and there are cells with but slightly thickened walls. Certain cells of the pericycle, at first but slightly differentiated, form, at length, groups of very thick-walled cells.

The pith is composed of large cells with thin, unlignified walls. It is found to be practically in the center of the section, though Pedicino [1876] found that when the plant climbs the pith is eccentric. About the time that the seedling has developed one internode above the epicotyl a medullary cambium has begun to form in the epicotyl. This produces xylem without and phloem next the pith. Considerable masses of phloem may thus be formed. This peculiar cambium in *Tecoma* was noted by Sanio in 1864 and fully described later by De Bary [1884]. Young branches of the plant were studied by these investigators who did not examine seedlings.

Cork formation, as previously described by Moeller [1882] for young branches, takes place in the second layer of the cortex. The cork cells are nearly square in cross section.

Comparison of the Structure of Hypocotyl and Epicotyl.

Although both hypocotyl and epicotyl are originally cylindrical, only the former remains so, the latter developing four thickened areas which make it somewhat quadrangular.

The four small groups of sclerenchyma in the pericycle of the hypocotyl are represented in the other region by a considerable number of smaller groups forming an interrupted ring. The endodermis remains distinct in the hypocotyl for a longer time than in the epicotyl. The medullary cambium is formed later and is less active.

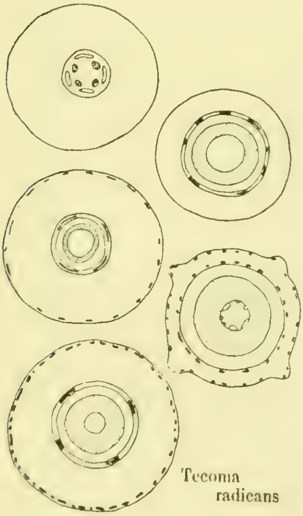


FIG. 21.

Catalpa speciosa.

Structure of Hypocotyl.

The epidermis consists of small cells, square in cross section. Short, blunt epidermal hairs are rather numerous. No hypoderma is developed; all the cortical cells are thin-walled.

The endodermis remains distinct for a long time. It consists of thin-walled cells which are but slightly smaller than the cells of the cortex. Starch is present, from the first, in the endodermis and toward the close of the season appears sparingly distributed in medullary rays and cortex; it is apparently absent from the pith.

The stele is small; in cross section it is circular. There are at first six, seven or eight conjoint vascular bundles arranged in a circle. Eight is probably the original number, but fusions often take place between adjoining bundles. Complete zones of xylem and phloem are formed at an early stage. About this time four small groups of sclerenchyma appear in the pericycle; they are equidistant. These eventually become somewhat divided, and other cells of the pericycle become sclerotic, so that a number of small groups of stereom are found in this area.

The pith is small in amount. The cells are large, with thin, slightly lignified walls. There is a perimedullary zone of small cells containing starch.

Cork formation takes place in the outermost layer of cortical cells.

Structure of Epicotyl.

The epidermal cells at first are oblong in cross section; the long axis is at right angles to the periphery of the section. Later the shape is more nearly square. There are many straight, blunt epidermal hairs.

The first two or three cell layers of the cortex are collenchymatous. The other layers are rather small-celled parenchyma.

The endodermis, though at first distinct on account of the presence of starch in its cells, was not recognized in older material. Starch is absent from the other tissues in the early stages, but is at length found in the cortex, phloem, medullary rays and perimedullary zone.

Toward the end of the first year a narrow, much interrupted ring of sclerenchyma appears at the outer edge of the phloem. The cells are small with very narrow lumen.

The number of vascular bundles is somewhat variable. About twenty is the usual number. These soon unite to form zones of xylem and phloem.

The pith is large, the cells thin-walled parenchyma. There is a perimedullary zone of small cells containing starch.

Cork arises in the outermost hypodermal layer, as it does in the stem of *Catalpa catalpa* (cf. Moeller [1882], p. 184).

Comparison of Structure of Hypocotyl and Epicotyl.

The epidermis of the hypocotyl has fewer and shorter hairs than that of the epicotyl. The former region has no hypoderma, though in the epicotyl a distinct collenchymatous zone is developed.

The endodermis of the hypocotyl remains distinct for a much longer time than that of the epicotyl; the stele has about eight vascular bundles, instead of twenty or more; sclerenchyma is first disposed in four groups instead of a considerable number.

The pith of the hypocotyl is much smaller in amount than that of the epicotyl.

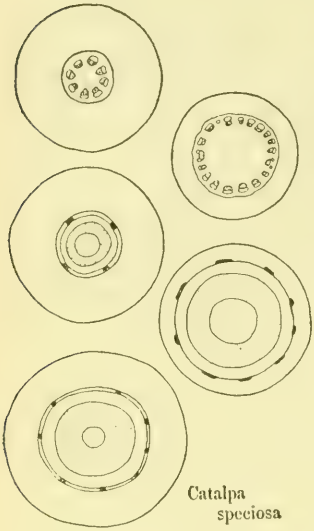


FIG. 22.

RUBIACEÆ.

Cephalanthus occidentalis.

Structure of Hypocotyl.

The cells of the epidermis are oblong or somewhat hexagonal in cross section. About every fifth or sixth cell is elongated radially and pointed, projecting somewhat beyond the general line of cells. These might be described as extremely short hairs. This characteristic feature continues for a considerable length of time.

No distinct hypoderma is formed. The cells of the two or three outer layers of the cortex are rather thick-walled but not collenchymatous. The cortex is loose with numerous large intercellular spaces.

The endodermis is large-celled. It remains distinct through the first year although the cells become at length very much flattened. They contain starch. Starch is later found in the various parenchymatous tissues.

The stele is circular in cross section. There are originally four phloem bundles and an equal number of xylem bundles; they are grouped in pairs. The xylem and phloem soon form closed zones, the xylem encroaching upon the pith which, at the close of the first season is almost entirely obliterated. The hypocotyl thus assumes a root-like structure—"rhizelle" of Van Tieghem [1891].

The cork is of epidermal origin.

Structure of Epicotyl.

The epidermal cells are rectangular in cross section. The radial is the long diameter at first but eventually the two diameters are nearly equal. Many of the cells are prolonged to form pointed hairs which are about three times as long as the ordinary cells of the epidermis.

A narrow collenchymatous hypoderma is developed; this shades off gradually into the ordinary cortex, which is quite extensive.

The endodermis is rather large-celled, the cells resembling those of the cortex but containing starch. The endodermis remains distinct throughout the first year. Starch, which is at first absent from the other tissues, becomes, at length, distributed through all the parenchymatous elements.

The stele, originally elliptical in cross section, follows the general shape of the epicotyl. Eventually the epicotyl becomes cylindrical as does also the stele. In the youngest material examined, the phloem forms a complete zone surrounding a ring of about six xylem bundles, which soon fuse to form a closed ring.

A few of the cells of the pericycle become sclerotic after a time. These are generally isolated; not aggregated in groups.

The pith becomes quite small; it is surrounded by a well-developed small-celled perimedullary zone whose elements contain starch.

The cork, like that of the hypocotyl, arises in the epidermis.

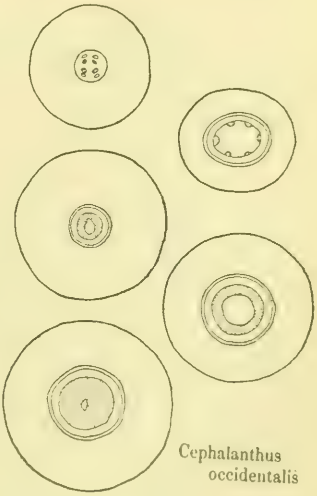


FIG. 23.

Comparison of Structure of Hypocotyl and Epicotyl.

The hypocotyl differs from the epicotyl in its shorter epidermal hairs, in the absence of a true hypoderma and in the much looser parenchyma of its cortex.

The structure of the stele is also very different, the hypocotyl having originally four phloem bundles and four xylem bundles, while in the epicotyl the phloem, even in the youngest stage examined, forms a closed ring surrounding six xylem bundles.

At the end of the first year the structure of the two regions is essentially the same except that the hypocotyl is without pith or differentiated hypoderma.

GENERAL CONCLUSIONS.

The following summary and conclusions are based on the facts shown in the foregoing pages. It is not intended to repeat here all the points which are there given, but merely to bring together under appropriate headings the most important facts of structure of the hypocotyl and epicotyl in the plants studied.

General Shape of Hypocotyl and Epicotyl.—In cross section the hypocotyl is usually circular in outline, the epicotyl is, however, not infrequently hexagonal in outline and somewhat flattened. The hypocotyl has usually in early stages much the greater diameter.

Comparison of the Epidermis of Hypocotyl and Epicotyl.—The epidermal cells of both regions when seen in cross section appear at first square or radially elongated. After a time, however, they became elongated tangentially, being stretched by the growth of the stelar tissues and not continuing to divide. In quite young stages some plants have in the epicotyledonary region, epidermal cells which, in cross section, appear tangentially elongated, viz.: *Ulmus americana*, *Liriodendron tulipifera*, *Butneria florida*, *Cercis canadensis*. Trichome structures are usually fewer and less complex in the hypocotyledonary region, *e. g.*, *Ulmus americana*, *Broussonetia papyrifera*, *Butneria florida*, *Robinia pseudacacia*, *Ailanthus glandulosa*, *Catalpa speciosa*, *Cephalanthus occidentalis*. In the following species the epicotyl has trichome structures but they are absent from the hypocotyl: *Celtis occidentalis*, *Toxylon pomiferum*, *Gleditsia triacanthos*, *Ptelea trifoliata*, *Rhamnus purshiana*, *Elæagnus umbellata*, *Tecoma radicans*.

Hypoderma in the Hypocotyl and Epicotyl.—Only one of the species examined has a definite collenchymatous hypoderma in both regions. This is *Butneria florida*. The following plants have a hypoderma in the epicotyl, but not in the hypocotyl: *Celtis* *occidentalis*, *Broussonetia papyrifera*, *Liriodendron tulipifera*, *Menispermum canadense*, *Gleditsia triacanthos*, *Robinia pseudacacia*, *Ptelea trifoliata*, *Ailanthus glandulosa*, *Rhamnus purshiana*, *Catalpa speciosa*, *Cephalanthus occidentalis*.

Comparison of Cortex of Hypocotyl and Epicotyl.—The cortical cells of the hypocotyl are nearly always much larger than those of the epicotyl. This is so commonly the case that various species need not here be specially mentioned; a good example is *Parkinsonia aculeata*. The cortex of the hypocotyl is thicker than that of the epicotyl.

Comparison of Endodermis and Pericycle in Hypocotyl and Epicotyl.—The endodermis in the hypocotyl is, as a rule, more distinct and persists longer than that of the epicotyl. Its cells contain starch. Pericycle is well developed in the hypocotyl, usually consisting of two or more layers of small cells.

Typical Structure of the Stele of the Hypocotyl. The stele is usually somewhat quadrangular. As a rule there are four phloem bundles and four xylem bundles. The phloem and xylem may be in contact or they may be separated by a small amount of undifferentiated parenchyma. In the latter case each phloem area is either directly outside of a xylem area (when the phloem may be spoken of as opposite the xylem), or the phloem bundles are removed from the xylem by greater or less angular distances (alternate arrangement). Using the foregoing terminology the arrangement of bundles may be described as opposite in the following: *Liriodendron tulipifera*, *Menispermum canadense*, *Butneria florida*, *Cercis canadensis*, *Amorpha fruticosa*, *Ptelea trifoliata*, *Ailanthus glandulosa*, *Schinus molle*, *Berchemia racemosa*, *Rhamnus purshiana*, *Vitis cordifolia*, *Cephalanthus occidentalis*. It is alternate in *Eucalyptus globulus* and *Tecoma radicans*.

Certain modifications of the more usual type just described would best be noted separately. There are four xylem bundles and eight phloem bundles in *Robinia pseudacacia*. In *Parkinsonia aculeata*, *Gleditsia triacanthos* and *Elæagnus umbellata* there are eight xylem bundles and four phloem bundles. The xylem bundles soon fuse together in pairs in the last two named species. In *Celtis occidentalis* and *Toxylon pomiferum*, the phloem forms two crescent-shaped areas while the arrangement of the xylem is normal.

Unusual Structure of the Stele of the Hypocotyl.—In certain species the stele of the hypocotyl does not have the typical structure just mentioned, the number and arrangement of vascular bundles being different. *Ulmus americana* has two xylem crescents and numerous small phloem bundles; *Broussonetia papyrifera* has a root-like structure; in *Catalpa speciosa* there are about eight vascular bundles.

Primary Structure of the Stele of the Epicotyl.—In shape the stele of the epicotyl is often originally somewhat hexagonal, though, as in the case of the hypocotyl, becoming at length cylindrical. As is well known there are usually from six to very many vascular bundles. Sometimes the phloem is completely fused into a closed zone even in very young stages.

Arrangement of Sclerenchyma in the Hypocotyl. The sclerenchyma of the hypocotyl first appears as four masses in the pericycle in *Toxlyon pomiferum*, *Liriodendron tulipifera*, *Cercis canadensis*, *Gleditsia triacanthos*, *Robinia pseudacacia*, *Ailanthus glandulosa*, *Vitis cordifolia*, *Eucalyptus globulus*, *Tecoma radicans* and *Catalpa speciosa.* In the plants just named this original disposition of the sclerenchyma becomes altered either by the intercalation of parenchymatous elements in the areas of sclerenchyma or by the development of sclerenchyma at other points. In the following plants, however, there is practically no change in the sclerenchyma during the first year and the four original masses remain to the end of the season: *Parkinsonia aculeata*, *Amorpha fruticosa*, *Ptelea trifoliata*, *Berchemia racemosa.*

Comparison of the Hypocotyl and Epicotyl with Reference to the Distribution of Sclerenchyma. Commonly the sclerenchyma in the two regions becomes, at the close of the first growing season, equally well developed and similarly arranged. Exceptions to this rule will now be noted. Sclerenchyma is absent from the hypocotyl of *Menispermum canadense*, *Butneria florida* and *Rhamnus purshiana* although present in the epicotyl. In *Ptelea trifoliata* and *Berchemia racemosa* at the close of the first year there is a greater development of sclerenchyma in the epicotyl than in the hypocotyl. The reverse of this condition obtains in *Celtis occidentalis* and *Eucalyptus globulus.* Only scattered sclerenchyma in small amount was recognized in either region in year-old material of *Broussonetia papyrifera;* in *Cephalanthus occidentalis* a few only of the pericyclic cells of the epicotyl become sclerotic.

Cork Formation in Hypocotyl and Epicotyl. The cork cambium is developed in the layer of cells next below the epidermis in both hypocotyl and epicotyl of *Celtis occidentalis*, *Liriodendron tulipifera*, *Butneria florida*, *Ptelea trifoliata*, *Ailanthus glandulosa*, *Catalpa speciosa*. In *Cephalanthus occidentalis* it is of epidermal origin in both regions. In the following species cork formation is sub-epidermal in the epicotyl but the cork is produced in deeper cell layers of the hypocotyl: *Ulmus americana*, *Toxylon pomiferum*, *Broussonetia papyrifera*, *Rhamnus purshiana*, *Elæagnus umbellata*, *Eucalyptus globulus*. In *Cercis canadensis*, *Gleditsia triacanthos*, *Amorpha fruticosa*, *Robinia pseudacacia*, *Vitis cordifolia* and *Tecoma radicans* cork formation in the epicotyl is cortical, while in the hypocotyl it takes place in some cases in the same cell layer, in other cases in deeper layers. Details are given in the previous descriptions for the separate species.

Pith and Perimedullary Zone of Hypocotyl and Epicotyl. The pith of the hypocotyl is smaller than that of the epicotyl, sometimes it becomes nearly obliterated, *e. g.*, *Cephalanthus occidentalis*. The perimedullary zone is sometimes not distinguished in the hypocotyl though present in the epicotyl, *e. g.*, *Parkinsonia aculeata*, *Gleditsia triacanthos*, *Eucalyptus globulus*. The opposite condition is found in *Cercis canadensis* and *Berchemia racemosa*. More often where a perimedullary zone is recognized it is equally developed in both hypocotyl and epicotyl.

Structure of Hypocotyl and Epicotyl at the close of the first year's growth.—Owing to secondary changes the two regions, though at first quite dissimilar in structure, may come to be very much alike. The xylem and phloem always form closed rings; the endodermis often becomes indistinguishable; the cells of the cortex become flattened. The differences of pith, perimedullary zone and sclerenchyma have already been given.

Condensed Summary.

Although secondary changes may cause a great resemblance in the structure of hypocotyl and epicotyl, the two regions are, in their primary structure, essentially dissimilar.

The epidermis of the hypocotyl is more often without trichome structures, the cortex is thicker and composed of larger cells, the endodermis is more distinct and persists for a greater length of time, the pith is smaller, sclerenchyma is often less well-developed and differently arranged and a hypoderma, so common in the epicotyl, is nearly always absent. Cork formation in the hypocotyl begins either in the same cell-layer that it does in the epicotyl or in a deeper layer, never in a more superficial one.

Starch is, as a rule, distributed in the same way in both regions. It is usually present in the endodermis in the early stages but does not appear in other tissues until the plant has developed foliage leaves, in considerable number.

As to the structure of the stele it may be said that in the hypocotyl there are usually four primary vascular bundles. The exact disposition of the phloem and xylem elements is subject to some variation. Occasionally there are more than four bundles. In the epicotyl the vascular bundles are from six to eight or very many.

The hypocotyl does not have a root-like structure.

Explanation of Plates.

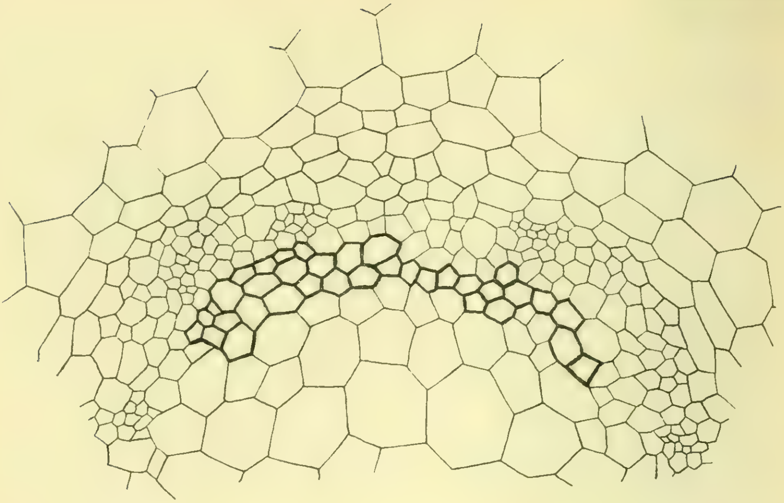
Plate V. Drawings of cross sections to show the primary stelar structure of the hypocotyl of *Ulmus americana*, *Celtis occidentalis*, *Toxylon pomiferum* and *Broussonetia papyrifera*.

Plate VI. Drawings of cross sections to show the primary stelar structure of the hypocotyl of *Menispermum canadense*, *Butneria florida*, *Amorpha fruticosa*, *Robinia pseudacacia* and *Ptelea trifoliata*.

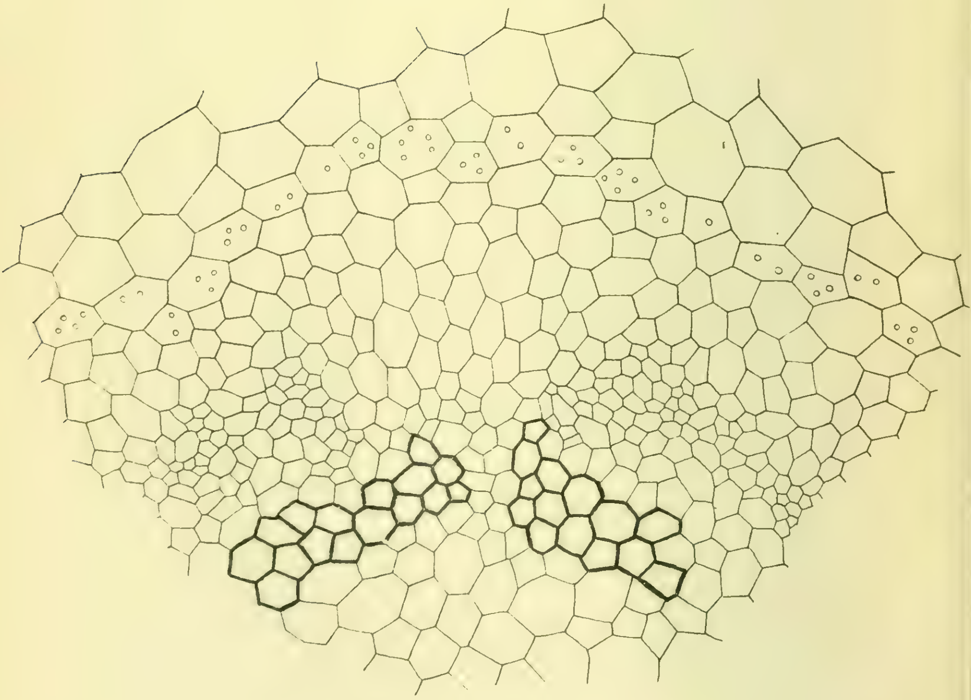
Plate VII. Drawings of cross sections to show the primary stelar structure of the hypocotyl of *Ailanthus glandulosa*, *Schinus molle*, *Berchemia racemosa*, *Eucalyptus globulus*, *Catalpa speciosa* and *Cephalanthus occidentalis*.

Plate VIII. Photographs of cross sections to show the primary structure of the hypocotyl. 1. *Ulmus americana*, 2. *Liriodendron tulipifera*, 3. *Parkinsonia aculeata*, 4. *Cercis canadensis*, 5. *Berchemia racemosa*, 6. *Vitis cordifolia*, 7. *Eucalyptus globulus*, 8. *Tecoma radicans*.

The drawings were all outlined with the aid of a camera lucida. The magnification used was about five hundred diameters. For publication the drawings have been reduced to one-half their original size. The magnification used in making the photographs was from fifty to eighty diameters. They have been slightly reduced. All drawings and photographs were made by the author from his own preparations.



Ulmus americana



Toxylon pomiferum

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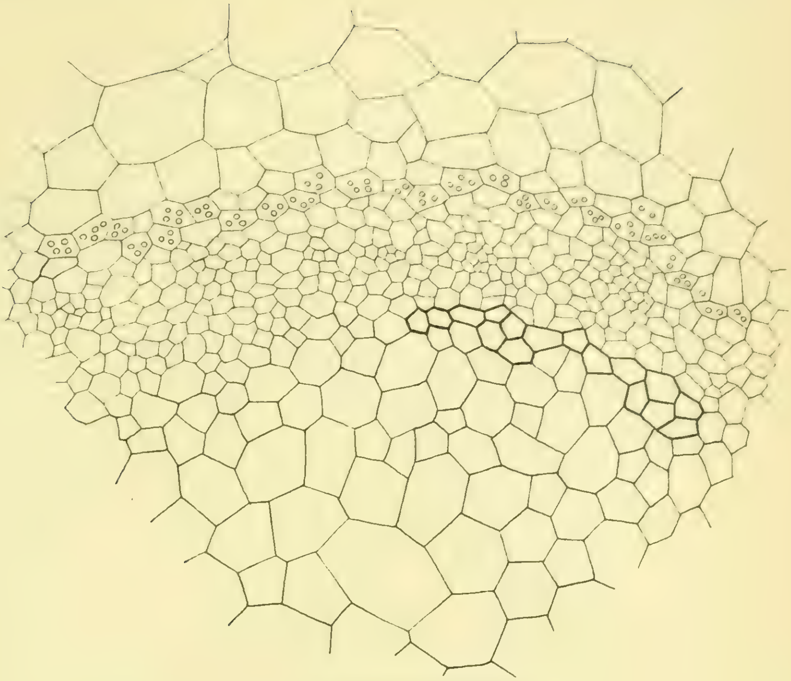
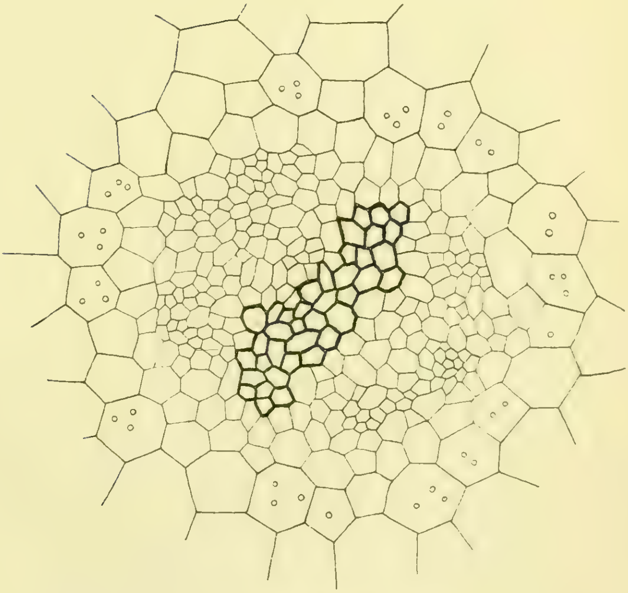


Celtis occidentalis



Broussonetia papyrifera

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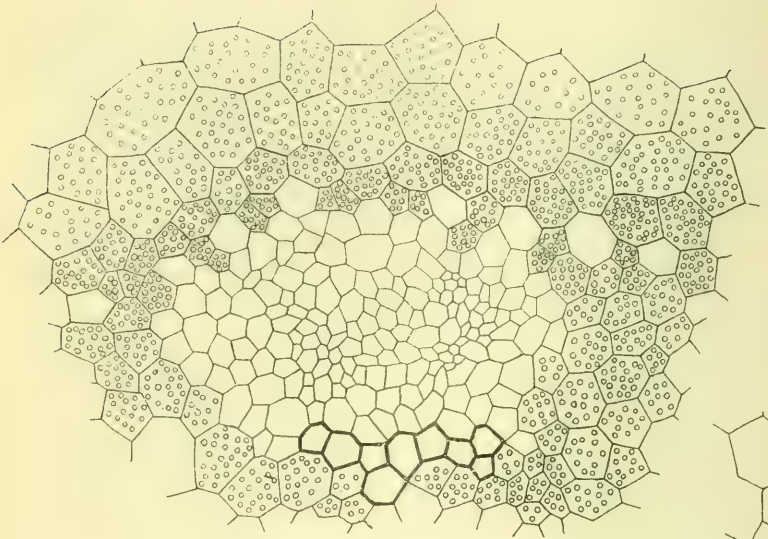
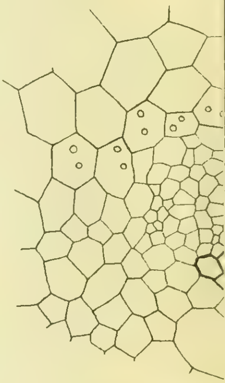
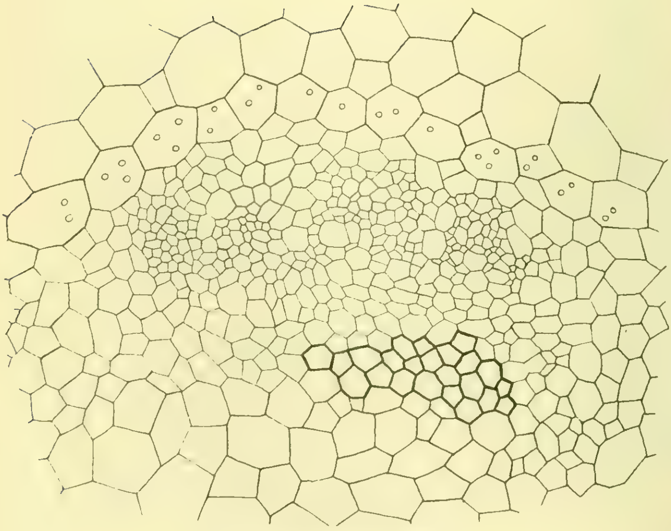


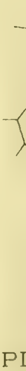
Menispermum canadense



Amorpha



Butneria florida



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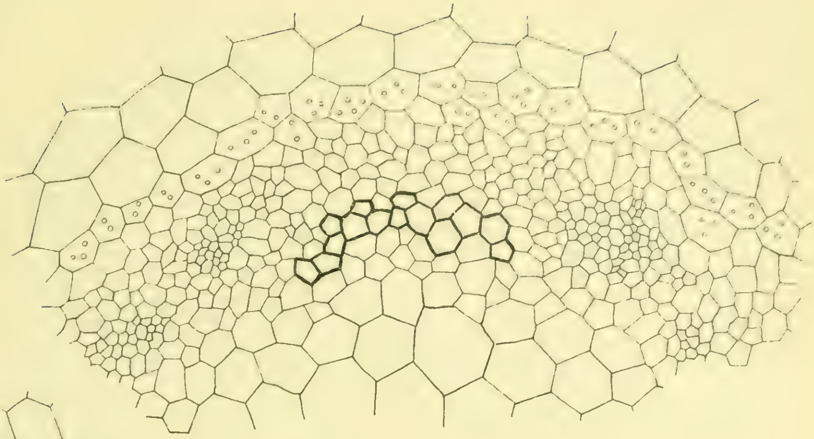
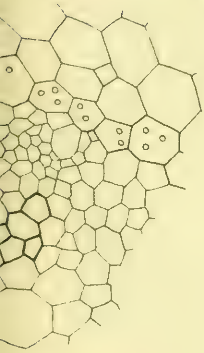


Robinia pseudacacia



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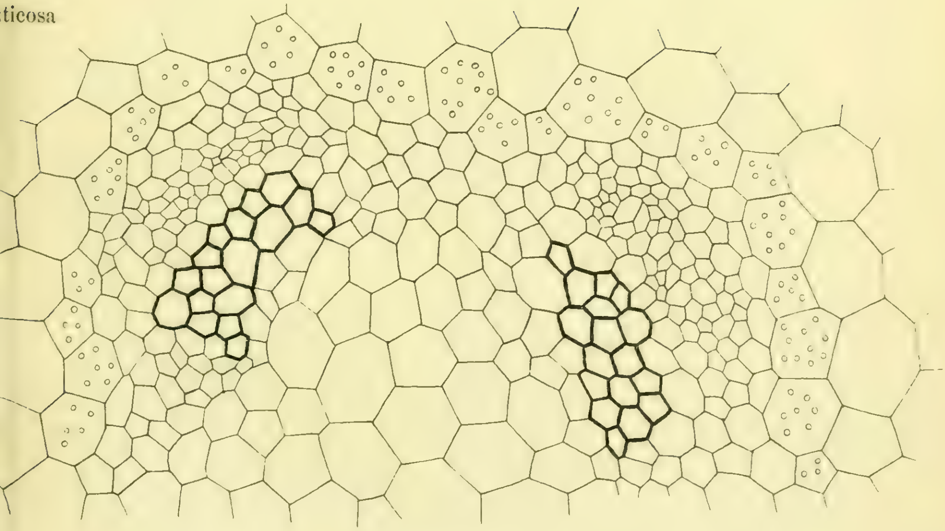

Ptelea trifoliata

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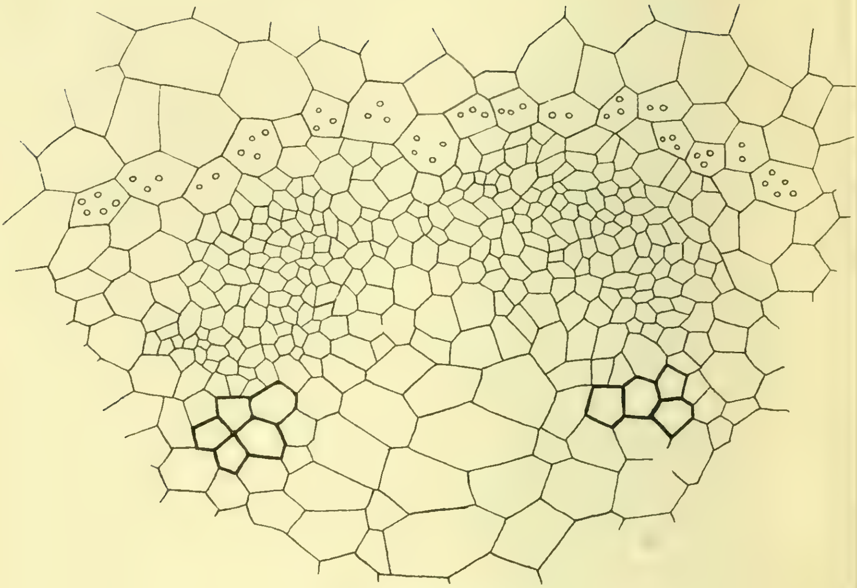
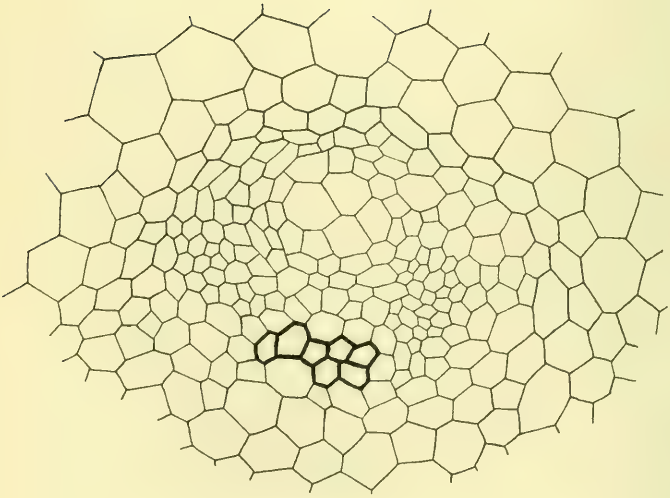
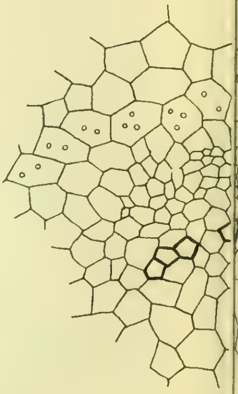


Ailanthus glandulosa



Schinus molle



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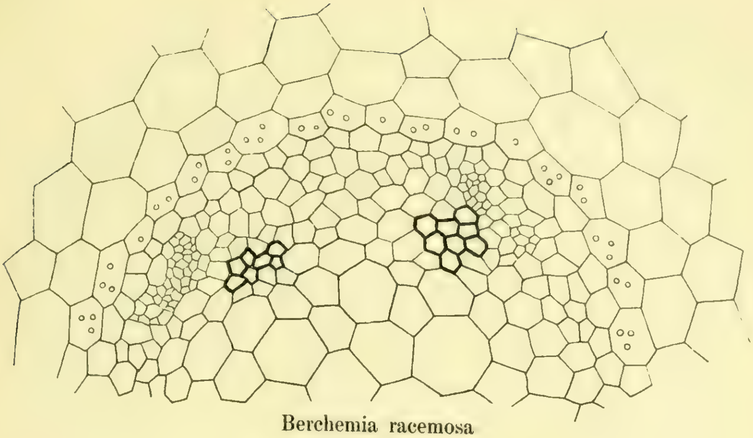
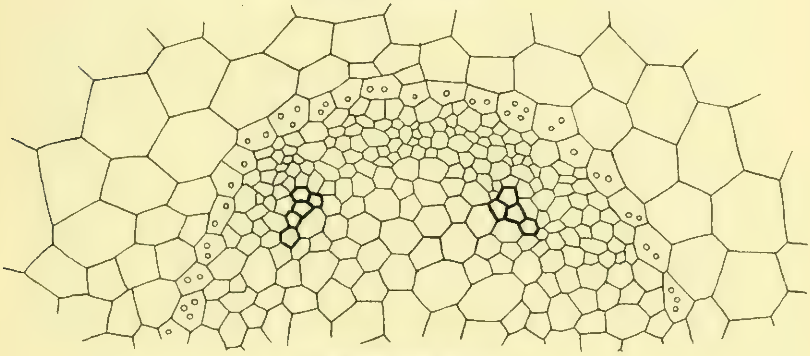
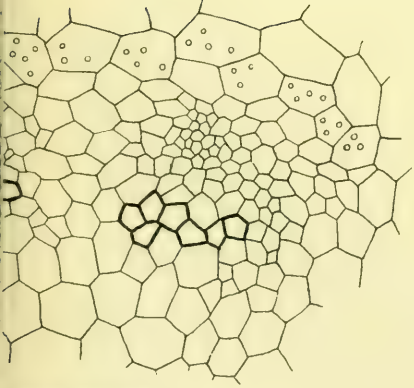


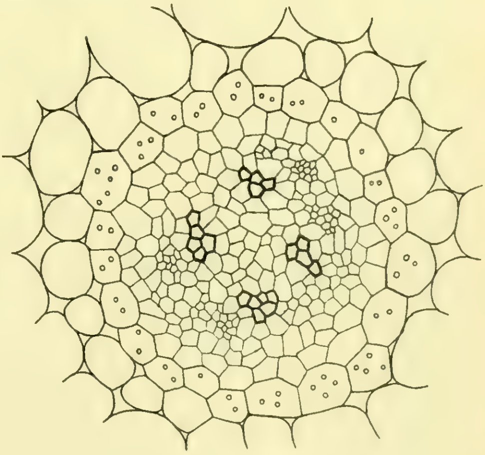
Berchemia racemosa



Eucalyptus globulus



atalpa speciosa



Cephalanthus occidentalis

VII.

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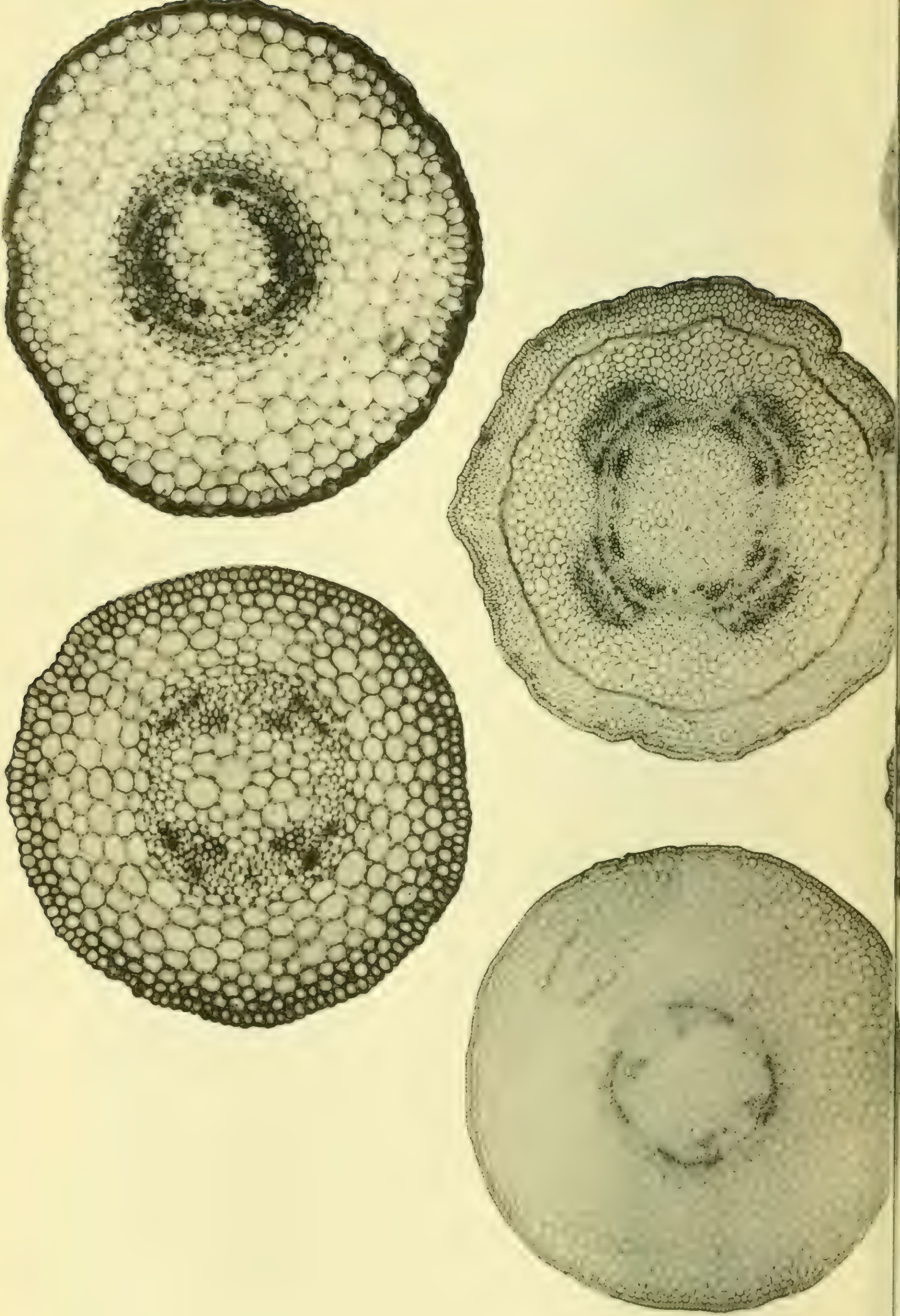

Ulmus americana
Berchemia racemosa

Parkinsonia aculeata
Cercio canadensis

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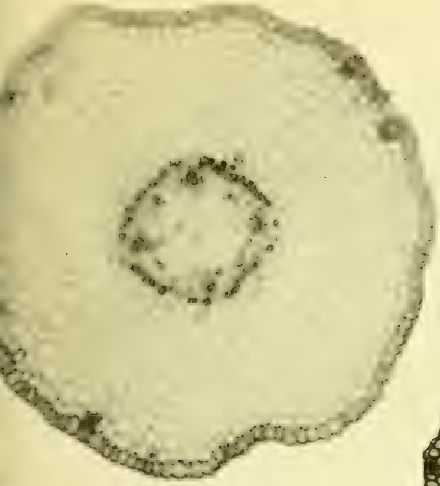

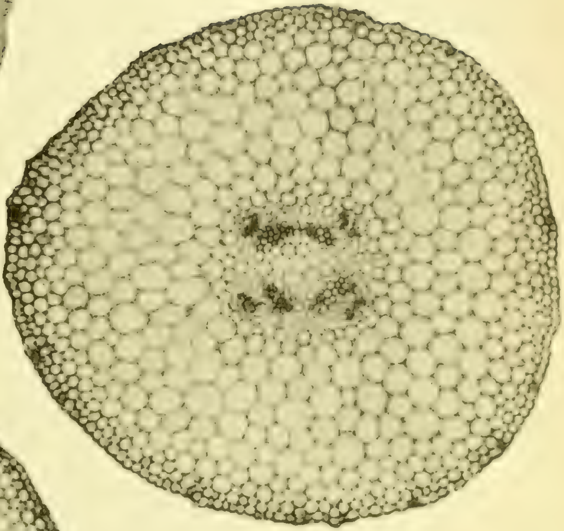

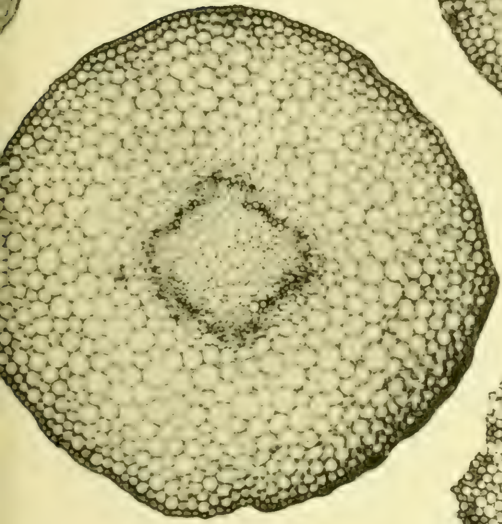

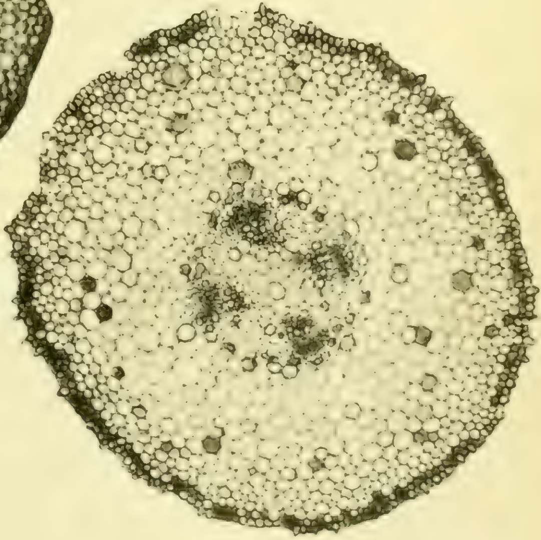

Eucalyptus globulus
Tecoma radicans

Liriodendron tulipifera
Vitis cordifolia

E VIII.

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BIBLIOGRAPHY OF ARTICLES TO WHICH REFERENCE IS MADE IN THE FOREGOING PAPER.

Dangeard, P. A. Le mode d'union de la tige et de la racine chez les angiospermes. Comptes rendus. 2e Sem. **107**: 287. 1888.

Dangeard, P. A. Rech. sur la mode d'union de la tige et de la racine chez les dicotylédones. Le Botaniste. **1**: 75. 1889.

De Bary, A. Compar. Anat. of the Vegetative Organs of the Phanerogams and Ferns. English translation. 1884.

Flot, Léon. Sur la region tigellaire des arbres. Comptes rendus. 1er Sem. **108**: 306. 1889.

Flot, Léon. Rech. sur la structure comparée de la tige des arbres. Rev. gén. de Bot. **2**: 17–32, 66–77, 122–136. 1890.

Flot, Léon. Rech. sur la zone périmédullaire de la tige. Ann. Sc. Nat. Bot. VII. **18**: 37. 1893.

Gérard, R. Rech. sur la structure de l'axe au-dessous des feuilles séminales chez les dicotylédones. Comptes rendus **90**: 1295. 1880.

Gérard, R. Rech. sur le passage de la racine à la tige. Ann. Sc. Nat. Bot. VI. **11**: 279. 1881.

Goldsmith, Sophie. Beiträge zur Entwicklungsgeschichte der Fibrovasalmassen im Stengel und in der Hauptwurzel der Dicotyledonen. Inaug. Diss. Zürich, pp. 48. 1876.

Herail. Rech. sur l' anat. comp. de la tige des dicotylédones. Ann. Sc. Nat. Bot. VII. **2**: 203. 1885.

Hovelacque, Maurice. Charactères anatomique genereaux de la tige des Bignoniacées. Bull. Soc. d'Études scientif. de Paris, 11me année. 1888.

Irmisch, Th. Einige Beobachtungen an *Eucalyptus globulus* Lab. Zeitschr. f. ges. Naturwiss. **48**:—1876. (Just. Bot. Jahresbericht **4**: 440. 1878.)

Klebs. Beiträge zur Morph. und Biol. der Keimung. Pfeffer's Untersuchungen aus dem Bot. Inst. zu Tübingen. **1**: 536. 1885.

Moeller, J. Anatomie der Baumrinden. 1882.

Pedicino, N. A. Studii sulla struttura e sulla maniera di accrescersi di alcuni fusti di piante dicotiledoni. Annuar. della R. Scuola Super. d'Agricoltura di Portici. 1876. (Just. Bot. Jahresbericht, Abt. I., **6**: 41. 1880.)

Sanio, C. Notiz über Verdickung des Holzkörpers auf der Markseite bei *Tecoma radicans*. Bot. Zeit. **22**: 61. 1864.

Trécul. Des vaisseaux propres dans les Terébinthinées. Comptes rendus **65**: 17. 1867.

Troschel, J. Untersuchungen über das Mestom im Holze der dicotylen Laubbäume. Verhandl. des Bot. Ver. der Provinz Brandenburg, **21**: 78. 1879.

Van Tieghem, Ph. Sur les canaux sécréteurs des Liquidambarées et des Simarubacées. Bull. Soc. Bot. France II. **6**: 247. 1884.

Van Tieghem, Ph. Sur la limite de la tige et de la racine dans l'hypocotyle des Phanérogames. Morot Journ. de Bot. **5**: 425. 1891.

Williams, J. Lloyd. The sieve tubes of *Calycanthus occidentalis*. Ann. of Bot. **8**: 367. 1894.

Woronin, M. Ueber d. Bau d. Stammes von *Calycanthus*. Bot. Zeit. **18**: 177. 1860.

X. CONTRIBUTION TO THE LIFE-HISTORY OF RUMEX.

BRUCE FINK.

Introduction.—The preliminary work leading to the present paper was nearly all done in the botanical laboratories of the University of Minnesota during the summers of 1896 and 1897. This work included a study of the macrosporangia and their contents in *Bursa bursa-pastoris* (L.) Britton, *Silene antirrhina* L., *Polygonum erectum* L., *Rumex acetosella* L., *Rumex salicifolius* Weinm., and *Rumex verticillatus* L.

At the close of the season of 1897, I had about an equal number of good preparations of the last two species and had learned that *Rumex verticillatus* is a much more favorable plant for study than *Rumex salicifolius* because of the larger size of the structures to be investigated. Consequently, during the latter part of August, 1897, after previous study of the former plant had enabled me to select methods which seemed best adapted to my purpose, a large number of flowers and buds, selected to represent various stages of development of the gametophyte, were preserved for future study. During the summer of 1898 over three thousand macrosporangia were sectioned, and the drawings presented with this paper were reproduced from the preparations that gave the best results. *Rumex salicifolius* was also further studied in 1898, and the series of slides of this plant is nearly as complete as that for *Rumex verticillatus*. As the two plants gave very similar results, except for size of structures, I have not thought it necessary to multiply figures by giving a full series for both plants. The figures then are, in the main, drawn from preparations from the latter plant; those from the former being introduced only when the equivalent phases of development were not found in the other plant, or were poorly exhibited in the preparations.

The plants of the genus studied are not well adapted to the study of nuclear mechanism and phenomena because of the small size of the cells and contained nuclei, and I have consequently confined myself to other phases of the subject. Nor have I found anything in the study that would give additional evidence as to the nature of various structures within the embryo sac so that my work resolves itself into a description of the gametophyte and some comparative studies.

Under the subject stated I shall, for the sake of relationships, begin with the archesporium, which is the last term in the sporophytic generation and also include stages immediately following the establishment of the sporophyte.

So far as I know this is the first work done on the female gametophyte of *Rumex*, or of any plant within the Polygonaceæ, except *Polygonum divaricatum*, which has been investigated by Strasburger.

I am under obligations to Professor Conway MacMillan for helpful suggestions as to technique and interpretation of structure and for access to the literature of the subject.

Origin of the Macrospore.—At about the usual stage in the development of the macrosporangium, an axial hypodermal cell at the summit of the nucellus begins to enlarge and soon contains a larger nucleus and denser cytoplasm than the surrounding cells (Fig. 1). This cell constitutes the archesporium, and in all instances examined, only one cell showed this archesporial nature. The archesporium in plants may develop directly into the macrospore ; it may itself become a sporogenous cell (mother cell) and divide into a number of potential macrospores ; or more commonly it divides first into a tapetum and a sporogenous cell, each of which may divide, forming a cellular tissue. In *Rumex* the last order of development is followed. After increasing considerably in size (comp. Figs. 1 and 2), the archesporium divides by a periclinal wall into the inner sporogenous cell (the mother cell of the macrospore), and the outer hypodermal tapetum (Fig. 2). This apparently protective tapetum proceeds next to divide, sometimes by a periclinal wall (Fig. 4), but no doubt much more commonly by an anticlinal (Fig. 3). In no instance did I observe more than four tapetal cells derived from the primary tapetum and often only three, one of the two derived from the primary tapetum apparently failing to divide. Indeed, sometimes only one tapetal cell could be distinguished at a period of development which led to the suspicion that the tapetum may sometimes fail to divide. Fig. 5 shows four tapetal cells and the sporogenous cell below somewhat more elongated than usual with its nucleus unusually near its upper end. That this elongated cell is the mother cell of the macrospore instead of the macrospore itself is proved by the outline of the inner seed coat, which shows its early development as compared with its more advanced condition before the macrospore is produced (Fig. 10). Fig. 6 represents a single tapetum lying above a dividing mother cell, and this may be the original tapetum which has failed to divide, though a cell lying almost directly below it, and hence not shown in the figure, may have been a second tapetal. Fig. 3 shows a typical mother cell apparently about ready to divide, and showing two tapetals, neither of which would be likely to divide again.

After the formation of the protective cap of tapetal cells and the enlargement of the mother cell of the macrospore, the latter divides as usual, among the Archechlamydeæ at least, into a row of four potential macrospores. It is here that our subject proper really opens since this mother cell, in which the reduction of chromosomes takes place, stands between the sporophytic and gametophytic generations, connected morphologically with the former and physiologically with the latter. As the mother cell divides the nucleus lies longitudinally at or a little above the center of the cell (Fig. 6). As elsewhere in these studies, the number of chromosomes could not be made out, but, in all probability through failure to get a complete view of individual chromosomes, there really seemed to be twenty-four in this nucleus. The two cells resulting from this division were not seen, but from the position of the dividing nucleus in several instances observed, it may be assumed that the division is into two cells of approximately equal size as observed by Strasburger* in *Polygonum divaricatum.* This dividing nucleus of the mother cell of the macrospore was about as large as that of the macrospore itself (Fig. 9) and, being like the latter a nucleus of a large well-fed and consequently somewhat inactive cell, was apparently a long time in dividing. The reduction of chromosomes is supposed to be a process involving more time than is commonly occupied in mitotic division of nuclei; and this process doubtless also added further to the time occupied by this mother cell nucleus in dividing, so that it was seen dividing much more frequently than the equally large and apparently as well-fed nucleus of the macrospore.

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* Strasburger, E. Die Angiospermen und die Gymnospermen, p. 5, 1879.

As stated above the two cells resulting from the division of the macrospore mother cell were not seen in the resting condition, though the four potential macrospores resulting from their division were frequently found. The two cells were seen once with their nuclei dividing, but the nuclei were indistinct because of improper staining. The two-celled condition, which was not seen, is doubtless a very transient phase, the upper of the two cells almost immediately cutting off a small cell from its lower end, and the lower of the two likewise dividing at once into two cells, a large one below and a small one above (Fig. 7). This four-celled stage seems to be constant and of quite long duration as it was frequently seen as represented in Fig. 7 or as in Fig. 10. In the latter the lower more successful cell which is to become the fertile macrospore has begun to absorb the other three potential macrospores for its own nourishment. This may be seen by observing the decrease in amount of cytoplasm contained in each of the three cells as compared with the same three in Fig. 7 and the swelling of the softened periclinal cell walls between any two of them and between the lowest one and the absorbing cell below. The next observed developmental condition was that in which the three cells were all absorbed except possibly a refractive cytoplasmic cap at the summit of the absorbing cell, which more probably represents a nearly absorbed tapetal cell (Fig. 8). This brings us to the macrospore as shown in the figure.

Germination of the Macrospore.—When first formed the macrospore has very nearly the shape of the four cells replaced and shows the nucleus at the center surrounded by cytoplasm, while the upper and lower ends are each occupied by a large vacuole. Though I cannot account for this apparent poverty in cytoplasm at this time, the condition seems to be typical. As the macrospore increases in size by the absorption of tapetal cells and those cells of the macrosporangium which surround its upper lateral wall, cytoplasm increases in amount (Fig. 9). In the figure the nucleus is lying in its usual longitudinal direction about the middle of the macrospore while dividing. Before the nucleus divides, the macrospore increases considerably in size by the absorption and pressing upon surrounding tissues (comp.

Figs. 8 and 9). The cavity of the macrospore, which I shall now designate by the usual name of embryo sac, continues to increase in size as it approaches the condition shown in Fig. 11 by the continual absorption and pressure upon surrounding cells. The relative position of cytoplasm and vacuoles in Fig. 9 is hardly normal, the nucleus of the macrospore more commonly lying along the central longitudinal axis of the spore. In another preparation showing the dividing nucleus of the macrospore, the nucleus was in this more usual position, and no vacuole was seen. Fig. 11 shows the two nuclei derived from the nucleus of the macrospore and two tapetals and two other sporangial cells nearly absorbed. Of these two nuclei it is quite common to find the lower one larger, probably as a result of better nourishment, and, apparently consequently giving rise in division to a larger number of chromosomes.

The condition as to chromosomes could not be studied, but I noticed relative sizes carefully. As instances of difference in size of the two nuclei, the researches of Sargant,* Mottier† and Guignard‡ may be cited. I examined a number of the embryo sacs showing the two nuclei, and it would seem that the lower nucleus becomes very slightly larger than the upper (Figs. 11 and 12). The slight difference may not be constant, and indeed in the closely related *Polygonum divaricatum* Strasburger§ shows the upper nucleus larger than the lower. This stage of development was quite frequently observed, but the next, in which two nuclei appear in each end of the sac, was only seen twice (Figs. 13 and 14). The first of the two figures shows the probable position of the two nuclei during division as a persistent spindle was seen between the anterior pair. Then the anterior pair seems to result from the division of a nucleus lying transversely in the anterior end of the sac and the posterior pair from a posterior nucleus lying longitudinally in the sac. This position of the two nuclei while dividing is the common one in plants so far as I can ascertain. Fig. 14 represents a later stage, in which the

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*Sargant, Ethel. The Formation of the Sexual Nuclei in *Lilium martagon.* I. Oögenesis. Annals of Bot. 10: 464. S. 1896.

†Mottier, David M. Ueber das Verhalten der Kerne bei der Entwicklung des Embryosack und die Vorgänge bei der Befruchtung. Jahrbücher für wissenschaftliche Botanik 31: 132. 1897.

‡Guignard, L. Nouvelles Études sur le Fecundation. Ann. des Sci. naturelles Botanique VII. 14: 187. 1891.

§Strasburger, E. l. c. Fig. 15.

nuclei have changed position somewhat. A difference in size has frequently been observed here also, in some other plants the lower pair being larger. I may cite Guignard[*] again and also Mottier.[†] However, the last named investigator only states that the nuclei forming the lower pair are much larger just before dividing, distinctly stating[‡] that at an earlier period the four are all of equal size. I did not observe this phase of development often enough to be certain that the size is the same at all times in *Rumex;* but it seems from the instances observed that, though coming from the nuclei differing somewhat in size, the four are so nearly of the same size at all times that any difference would be difficult to detect. During the change to the four-nucleate condition the sac increases somewhat in size, as may be seen by comparing Figs. 13 and 14 with Fig. 12.

The development from the four-nucleate to the eight-nucleate condition must be even more rapid than that from the two-nucleate to the four-nucleate phase, for I was neither able to find the two tetrads in position, nor the division of the four nuclei leading to its establishment. The nearest approach to it was observed in *Rumex salicifolius* (Fig. 15), when the polar nuclei were approaching. The condition represented in Fig. 15 is an especially interesting step in the life-history of the gametophyte of *Rumex* because of departure from the usual conditions and especially from the nearly related *Polygonum*. On examining the figures of Guignard, Vesque, Strasburger, Ward and others, I find that in fully five-sixths of their drawings they show cell walls about the three anterior cells before the polars have fused. Strasburger figures for *Polygonum divaricatum* [§] three nuclei enclosed in cellular membranes and one free nucleus in each tetrad even before the two polars begin to approach each other. My own observations on *Polygonum erectum* L. (Fig. 16), *Bursa bursa-pastoris* (L.) Britton and *Silene antirrhina* L. gave the same results so far as the anterior end of the sac is concerned, though the evanescent antipodals of *Bursa* were not satisfactorily studied in this respect. Methods which brought out these walls in the three plants named above should show them, if present in *Rumex*, yet in this genus I find all the anterior three cells free while the polars are approaching each other in *Rumex salicifolius* (Fig. 15). When the polars have met, or are fusing in this plant, the cellulose walls seem to begin to form, and a suggestion of such a structure may occasionally be seen (Figs. 17 and 20) about the nuclei of the synergidæ. In *Rumex verticillatus*, even shortly after the definitive nucleus is formed (Fig. 18), I could only distinguish a suggestion of a beginning of formation of a membrane about the lower end of the egg while the sister nuclei which form the synergidæ were yet free. In *Rumex salicifolius* the synergidæ form earlier than in *Rumex verticillatus* and are more regular in form in the former plant (compare Fig. 24 with Figs. 19 and 23). So far as investigation has proceeded then, cell walls appear about the three anterior nuclei (excluding the anterior polar) before the meeting of the polar gametes in *Polygonum;* while in *Rumex* the walls appear after the meeting of the gametes, or even after their fusion to form the zygote constituting the definitive nucleus. The matter is one of some taxonomic interest, which can only be solved by a laborious study of all the species of the two genera with reference to this particular problem in developmental history.

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[*] Guignard, L., l. c. 188.

[†] Mottier, David M., l. c. 137.

[‡] Mottier, David M., l. c. 136.

[§] Strasburger, E. l. c. Fig. 17.

Regarding conditions presented in Figs. 15, 17 and 20 some further statements are necessary. In these stages I was able to note no difference in size of the three anterior nuclei, while at later periods the nucleus of the egg had increased in size so that it was larger than those of the synergidæ (Figs. 18 and 19). So far as I could ascertain, the nuclei of the three antipodals were smaller than the three just discussed at all periods. Fig. 17 represents the three antipodals as best seen in *Rumex salicifolius*, and here their smaller size can be seen distinctly. The antipodals are difficult of observation at all times because of their lying in the small cæcum-like prolongation of the embryo sac so that, except in very thin sections, other cellular structures of the surrounding macrosporangium almost always partially or completely obscure them. In the sac of the same plant showing a slightly earlier stage of development (Fig. 15), only the deeply-stained nucleoli could be seen through the overlying tissues of the macrosporangium, neither the nuclear membrane nor the cellular wall about each of the three nuclei appearing. In this plant the three-celled antipodal area was found persisting in the latest phases studied after the establishment of the embryonic sporophyte (Fig. 33) and seems to be quite constant, though in the sac represented in Fig. 24 I suspect that there were really no walls about the antipodal nuclei. However, here again overlying tissues may have obscured them. *Rumex verticillatus* gave less satisfaction in the study of the antipodal region. In only one instance were three antipodals seen constituting a three-celled mass of tissue (Fig. 21). This figure represents the posterior end of a mature sac. In other instances various conditions of cell-wall formation were shown in this region before the establishment of the sporophyte (Figs. 23, 27 and 28). Sometimes more than three nuclei could be distinguished within this antipodal area (Figs. 23 and 28). After fertilization these cells seem to disintegrate more or less in this plant, and no such typical structure was found persisting as is figured for *Rumex salicifolius* (Fig. 33). The degenerating condition of the antipodal region just after fecundation is shown in Fig. 27, which is the lower end of the sac presented in Fig. 26. Here I was only able to make out a highly refractive area with neither walls nor nuclei. As to the time when the cellular membranes appear around the antipodal nuclei, I am not able to state certainly because of the difficulty encountered in investigation, but it seems, from the facts presented and other observed phenomena, that in *Rumex salicifolius* they form earlier than those about the three nuclei in the anterior end of the sac. In *Rumex verticillatus* walls were not detected till the time of maturity of the embryo sac when the typical three celled condition (Fig. 21) presented itself, or that of three or more nuclei within a common wall (Fig. 23). The antipodal area in *Rumex salicifolius* seems to agree substantially with the third of the four types proposed by Coulter* of "three comparatively permanent cells not notable for size or activity and usually associated with a sac decidedly narrowed at the antipodal end." The antipodals of *Rumex verticillatus* are not so permanent, but doubtless should be classed here also as should those of *Polygonum erectum*.

The size of the two polars in plants may differ as well as their place of fusion. Schaffner finds the upper one larger in *Alisma plantago*† and *Sagittaria variabilis*.‡ Also he finds in

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*Coulter, John M. Contribution to the Life-History of *Ranunculus*. Bot. Gaz. **25**: 80–81. F. 1898.

† Schaffner, John H. The Embryo Sac of *Alisma plantago*. Bot. Gaz. **21**: 126. Mr. 1896.

‡ Schaffner, John H. Contribution to the Life History of *Sagittaria variabilis*. Bot. Gaz. **23**: 255. Ap. 1897.

the last plants that the two polars fuse in the lower part of the sac, the larger gamete strangely enough traveling further than the smaller and thus showing greater activity. Mottier* finds them of about the same size in *Senecio aureus* and that they fuse in the anterior end of the sac just below the egg, the lower of the two equal-sized polars thus showing greater activity. In *Rumex*, and all of the Polygonaceæ so far as studied, the two polar nuclei are of about the same size (Figs. 15, 17 and 20) and fused at or near the center of the sac.

During the passage from the four-nucleate to the eight-nucleate condition, the sac increases considerably in size (comp. Figs. 13 and 15), and the increase in size is even more noticeable as the sac matures (comp. Figs. 15 and 24).

The Mature Embryo Sac.—The mature sac contains typically the usual seven nuclei, though in *Rumex verticillatus*, as stated elsewhere, the number in the antipodal region may vary, producing a corresponding variation in the total number contained in the sac. In *Rumex verticillatus* the synergidæ are somewhat irregular in form (Figs. 19 and 23), while in *Rumex salicifolius* they are more regular in outline (Fig. 24). The egg usually lies in contact with the lower part of one synergid in both plants (Figs. 19, 23 and 24), and its nucleus is much larger than those of the synergidæ. All three nuclei are enclosed in definite walls at this time. The definitive nucleus is much the largest nucleus in the sac (Figs. 18, 23, 24, 25 and 28). In *Rumex verticillatus* it usually approaches the egg after formation and lies close to it till the time for fecundation approaches (Fig. 23) when it commonly recedes somewhat (Figs. 25 and 26). In *Rumex salicifolius* it usually lies at some distance from the egg in the mature sac (Fig. 24) though it was once seen nearer in an earlier stage (Fig. 22). In *Rumex salicifolius* it may be assumed that the antipodals are in the typical three-celled condition at maturity as they were observed in this condition both before and after as already stated (Figs. 17 and 33). As before noted the condition of the antipodals in Fig. 24 is doubtful. The condition of the antipodals in *Rumex verticillatus* at this time has also been explained above.

In shape the mature sac in both plants differs quite widely from that of *Polygonum divaricatum* as shown in Strasburger's

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[*] Mottier, David M. On the Embryo Sac of *Senecio aureus*. Bot. Gaz. 18: Fig. 1 and p. 248. Jl. 1893.

figure,* the largest part being near the anterior end and the posterior narrowed end being quite long (Figs. 17, 23, 24, etc.) while his figures show the narrowed posterior cæcum dilating quite abruptly, making the posterior half of the mature sac quite as large as the anterior half. *Polygonum erectum* the mature sac is much more like *Rumex* than *Polygonum divaricatum* as figured by Strasburger.

Fecundation, and the origin of the Sporophyte. During the period of fecundation and the establishment of the sporophyte, the embryo sac continues to increase in size rapidly, as may be seen by comparing Figs. 24 and 33 and also 23 and 30, making allowance for the greater reduction of Figs. 30 and 33.

The first evidence of a pollen tube approaching or already present in the sac is the disappearance of one of the synergidæ (Fig. 25). When actually present the tube is an easy object to detect because it stains more deeply than surrounding tissues, hence in those instances in which one synergid was breaking down while no tube could be distinguished, I have concluded that the tube was just approaching the sac. In Fig. 25 the tube has not yet discharged, as it shows two nuclei and the end is intact, and it lies as usual beside the persistent synergid. The definitive nucleus here occupies a position at some distance from the egg as it frequently does at this time. Here this nucleus is in a resting condition, and I find it so constantly up to this time. After the pollen tube has discharged the remaining synergid disappears, and the definitive nucleus soon divides (Fig. 26). Though in some plants the definitive nucleus seems to divide sometimes before the entrance of the pollen tube into the sac, its presence in the style probably furnishing the necessary stimulus, it does not divide till after the entrance of the tube in *Rumex verticillatus* and probably usually not till after the fecundation of the egg. In the discharge of the sperm nucleus the tip of the tube is ruptured as shown in Figs. 26, 29, 30 and 35. After the pollen tube has discharged a deeply stained spot may always be seen within the tube as shown in the same figures. This is the shrunken second and undischarged sperm nucleus. The fusion of the sexual nuclei was only seen once, and in that instance the egg was badly distorted. The tube in this case was closely applied to the egg though the figures given herewith seem to indicate that this is not the usual relation during fusion of these nuclei. The conditions existing in Fig. 28 are somewhat of an enigma. The sac is surely larger than it could be previous to fecundation, but the two smaller nuclei in the anterior end look like those of the synergidæ. Also the definitive nucleus lies near the egg as I uniformly find it in *Rumex verticillatus* before fecundation. I thought for a time that I had here a pollen tube showing one sperm nucleus within and the other discharged and entering the egg. However, taking into account the appearance of the two smaller nuclei and the restful condition of the egg, I have concluded that the sac is one whose egg failed to be fertilized and in which one synergid has disintegrated leaving its nucleus while the other is rapidly dwindling. If this is true, the sac has gone on increasing in size the same as if the egg had been fecundated. The next stage observed after that already explained (Fig. 26) is that represented in Fig. 30, in which the tube had discharged, the first two endosperm nuclei had divided and the spindles were persisting, and the egg was evidently preparing to divide. A little later phase was also found (Fig. 29), in which the tube was persisting and showed the broken end beautifully, the egg was dividing and three of a probable four endosperm nuclei were visible. The tube frequently persists in both plants till the sporophyte is well established (Fig. 35), and in one instance an undischarged tube was seen in the sac of *Rumex verticillatus* after the embryo was well established and four endosperm nuclei were dividing (Fig. 34). This tube, containing two sperm nuclei, is a second one which entered the sac after fecundation had been accomplished.

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* Strasburger, E. l. c. Fig. 21.

An exhaustive study of the embryo will not be attempted ; but I shall state a few observed facts concerning its origin and early development, making no use of the terms suspensor and proembryo, but designating the structure from the beginning as the embryo. The first division then of the embryo occurs soon after the egg has elongated and secreted a cellulose wall about its base to attach it to the anterior end of the sac and is transverse (Fig. 29). The second and third divisions were also transverse in several instances observed (Fig. 35), and the fourth was a longitudinal division of the distal cell of the embryo (Fig. 31). In an instance observed the third division was transverse and closely followed by a longitudinal dividing the second cell from the distal end (Fig. 32). During its early development the embryo is not always attached centrally at the anterior end of the sac, nor does it often lie in an exactly longitudinal direction in the sac.

It has already been stated that the definite nucleus in *Rumex* does not divide till after fecundation of the egg, an observation based upon examination of two or three hundred sacs. It is worthy of note that the endosperm nuclei observed while dividing in any given sac were all in the same mitotic phase (Figs. 30 and 34). The last figure shows only one of four nuclei observed dividing. The endosperm nuclei were not so numerous, at the stages studied, in *Rumex verticillatus* as in *Rumex salicifolius* (Fig. 33); nor were they yet enclosed in cell walls in either plant.

Relation of the Gametophyte to the Macrosporangium.—I have studied carefully the position of the base of the sporogenous tissues and derived embryo sac with reference to lines connecting the points of origin of the seed coats in order to ascertain how much of the enlargement of these structures is associated with a downward growth and consequent crowding of the tissues of the macrosporangium and how much is accomplished by upward growth, keeping pace with the growth of the nucellus. The position of the base of sporogenous tissue, and later of the sac, with reference to these lines is not always quite the same at any particular stage of development; but by comparative study, safe conclusions have been secured. Between the base of the archesporium and the lines connecting the supposed points of origin of the future seed coat are five or six cells. After the tapetum is cut off (Fig. 2), there are only three or four cells between the base of the mother cell of the macrospore and the lines. By the time of division of the tapetum (Fig. 3) the base of the mother cell is within two or three cells of these lines. During this time the nucellus has increased in length very little, its increase in size being principally in width. Consequently, this fact, together with the relative position of the base of sporogenous tissue and the lines at various stages of development, indicates that the sporogenous tissue has grown downward in the nucellus. As no evidence of absorption of cells was seen at this time, I conclude that this downward growth is accomplished by crowding downward and outward the subjacent layers of cells of the macrosporangium. However, the effects of the crowding were so distributed among several layers of cells that they were scarcely visible in any particular cell. After the mother cell has reached its full length, there is no further downward growth, the further increase in length of the sporogenous tissues and subsequently of the sac being accompanied by a proportionate elongation of the nucellus. By the time of the establishment of the macrospore, a thickening of the walls of cells in the chalazal region for the support of structures above has begun in a layer of cells extending transversely between the points of origin of the inner seed coat. As the superimposed structures become heavier, the thickening extends to several layers of cells below the ones first thickened and gives rise to quite a mass of thick-walled tissue extending entirely across the chalazal region.

As the macrospore matures and prepares to divide (Fig. 9), absorption of tapetals above and pressure on surrounding cells of the upper nucellus becomes evident and is apparent in all subsequent stages of development of the gametophyte. However, the swelling of the cell walls of the upper nucellar tissue just beneath the epidermis as observed by Strasburger* in *Polygonum divaricatum* as a result of absorption I have not seen either in *Rumex* or *Polygonum.*

By the time development has proceeded to the condition represented in Fig. 11, the subepidermal cells of the upper end of the nucellus have all been absorbed, and from this time on till the establishment of the conditions shown in Fig. 28, or possibly not later than those shown in Figs. 25 or 26, the increase in size is due, at least principally, to the absorption of cells of the nucellus surrounding the middle portion of the sac, which still continues to increase in size. During this time the sac is increasing in length, and since there has been no further sinking of its posterior end into subjacent tissues, as is shown by the fact that its lower end is still removed from the lines connecting the points of origin of the inner seed coat by two or three cells, as was the lower end of the mother cell, this increase in length is accompanied by an equal upward growth of the nucellus. Dividing nuclei were seen in the basal region of the nucellus, both in the epidermis and in the sub-epidermal cells, up to the latest stages studied, indicating that this basal portion of the nucellus is its chief region of growth at these stages. After the growing gametophyte has absorbed all the sub-epidermal tissues of the upper nucellus, the sac does not cease to expand laterally, but presses the remaining epidermis of this portion of the nucellus outward as it still further increases in size. These epidermal cells contain cytoplasm and may divide even after the cells of the inner nucellus, or their cytoplasmic contents, at least, have been absorbed; but the increase in epidermal surface accompanying the continued increase in size of the sac is doubtless due principally to increase in length of these upper epidermal cells and the division of those near the base of the nucellus.

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*Strasburger, E. l. c. Figs. 10 et seq.

Fig. 28 shows certain of these conditions of the nucellus brought about by absorption of its tissues by the growing gametophyte and by its own growth. All of the epidermal cells except those at the summit show elongation in the direction of upward growth of the nucellus. All of the epidermal cells except those at the summit are also well filled with cytoplasm, indicating activity. The lowest sub-epidermal cells of the nucellus shown in the figure are also well filled as were the cells of five or six layers lying between the lowest shown in the figure and the area of thickened cells in the chalazal region. In passing upward from the base to the summit of the nucellus, we find greater and greater absorption of the cytoplasmic cell-contents and finally a partial breaking down of the cell walls and a beginning of the consequent collapsing of the cells. In the lower portion of the nucellus the absorption by the gametophyte has only affected the layers of cells near the sac, while in the upper portions all of the sub-epidermal cells are affected. The upper and older cells of the nucellus, where not too much disintegrated, also show an increase in size over those of younger nucelli, which accounts in part for the elongation of this organ as it keeps pace with the growth of the sac.

Methods.—After trying one per cent. solution of osmic acid, one-half per cent. and one per cent. chromic acid, a saturated solution of corrosive sublimate in seventy per cent. alcohol and the last two plus a small addition of acetic acid to prevent shrinkage, the corrosive sublimate with acetic acid was found to give best results. The sections thus fixed also took best the stains used.

After this method of fixing, the tissues were washed in seventy per cent. alcohol containing iodine, gradually transferred to absolute alcohol, imbedded in paraffine through xylol, stained and mounted in balsam in the usual way. Alcohol safranin followed by methyl blue was found to be the best stain for stages before the establishment of the macrospore, and safranin or Delafield's hæmatoxylin gave best results from this period up to the fecundation of the egg, after which the hæmatoxylin proved best.

The nucellus of *Polygonum erectum* is transparent enough to show the nuclei of various stages of development of the sac, except the antipodals, as well as the cytoplasm and vacuoles with oil immersion lens, without sectioning or any treatment whatever. The results, however, were not reliable enough for my purpose, nor are they certain enough for use in instruction.

The figures are all drawn to the same scale by using one-inch Leitz eye piece, one and one-half-inch Leitz objective and camera lucida.

Explanation of Plates.

Note.—All figures are of *Rumex verticillatus* unless otherwise indicated. The figures of the first two plates are reduced to one-half the original size of drawings, those of the last two to one-third.

Plate IX.

1. Upper portion of nucellus showing the archesporium.

2. Later stage showing the primary tapetum cut off above and the mother cell of the embryo sac below.

3. The tapetum has divided into two tapetal cells and the mother cell has increased considerably in size.

4. Stage between 2 and 3 showing the tapetum dividing.

5. Four tapetal cells and the elongated mother cell.

6. The mother cell dividing and one tapetal cell above.

7. The four potential macrospores derived from the mother cell.

8. The macrospore and a highly refractive cytoplasmic cap, representing an almost completely absorbed cell, either a tapetal cell or the upper one of the potential macrospores.

9. The nucleus of the macrospore dividing.

10. A somewhat older stage than 7 and showing the upper three potential macrospores partly absorbed by the lowest one, which is to become the macrospore.

11. Embryo sac containing two nuclei resulting from the division of the nucleus of the macrospore, the lower one being somewhat larger. The highly refractive remains of four nearly absorbed cells of the nucellus are also shown.

Plate X.

12. Embryo sac of *Rumex salicifolius* showing the two nuclei as above and the lower one also slightly larger.

13. Embryo sac of *Rumex salicifolius* showing the four nuclei derived from division of two corresponding to those figured in 11 and 12, and also showing the persistent spindle in the anterior end of the sac.

14. Embryo sac of *Rumex salicifolius* showing the corresponding four nuclei in a somewhat older sac.

15. Embryo sac of *Rumex salicifolius* showing eight nuclei derived from four corresponding to those figured in 13 and 14. The polar nuclei are approaching each other. The three anterior nuclei are of about equal size and not enclosed in walls. Only the nucleoli of the antipodals could be seen.

16. Embryo sac of *Polygonum erectum* showing the earlier formation of cell walls about the anterior nuclei, one of which was lying below the other two. The polar nuclei are approaching each other, and the cellular structure in the antipodal area is distinct, one cell here also lying below the other two.

17. Embryo sac of *Rumex salicifolius* showing the egg yet free, cell walls forming about the synergidæ, the polar nuclei fusing and three distinct nucleated antipodal cells.

18. Embryo sac showing the sister nuclei which form the synergidæ yet free and the wall forming about the egg after the definitive nucleus is formed.

19. Anterior end of a mature embryo sac showing the synergidæ and the egg.

20. Embryo sac of *Rumex salicifolius* showing all of the nuclei of the mature sac, except the antipodals and at about the same stage as the corresponding nuclei in 17.

21. Posterior end of a mature embryo sac showing three antipodal cells.

22. Anterior end of the embryo sac of *Rumex salicifolius* showing walls forming about the egg after the definitive nucleus is formed.

23. Mature embryo sac showing more than three nuclei in the antipodal end.

24. Mature embryo sac of *Rumex salicifolius*, with the antipodal region perhaps not distinctly seen.

Plate XI.

25. Anterior end of embryo sac showing one synergid degenerated, the pollen tube entering and showing two nuclei very indistinctly. The egg and definitive nucleus are also shown.

26. Anterior end of embryo sac showing a pollen tube discharged and containing an undischarged sperm-nucleus. The two synergidæ

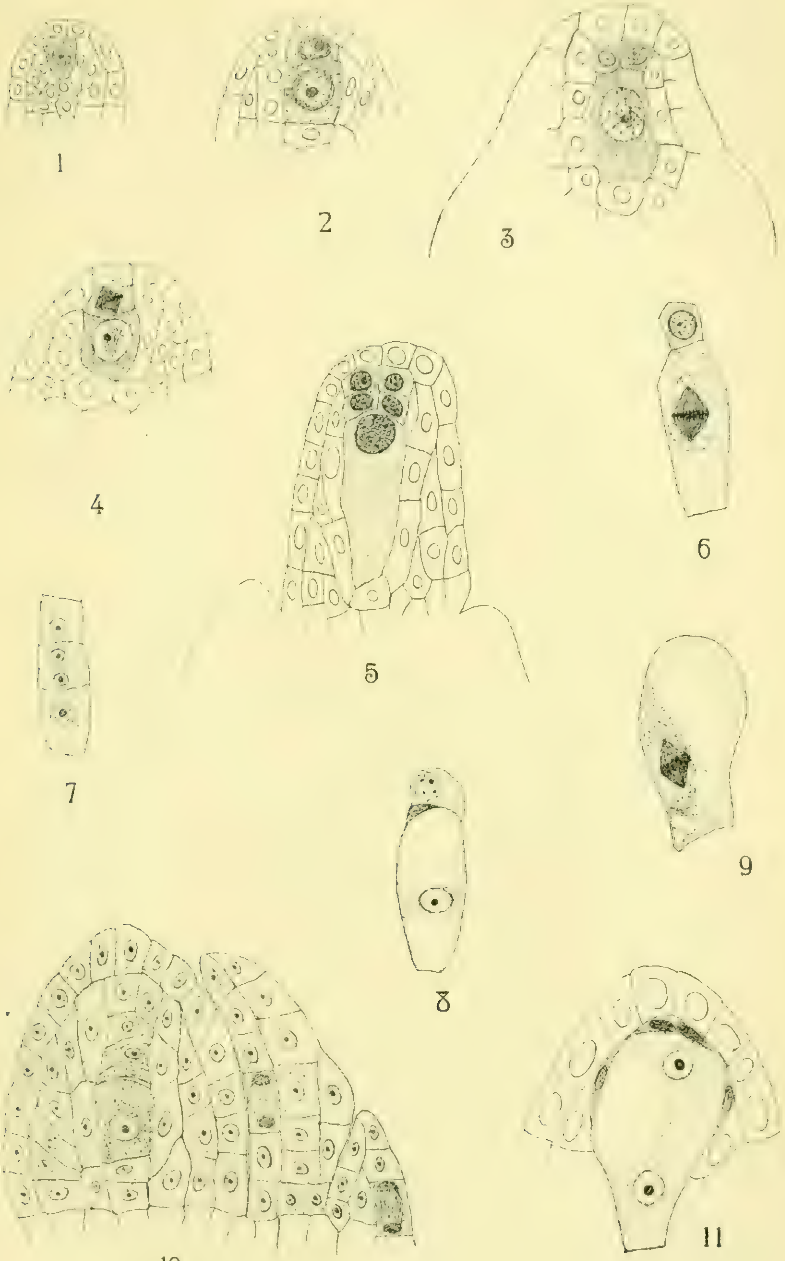

PLATE IX.

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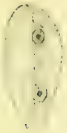

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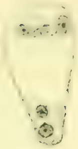

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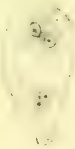

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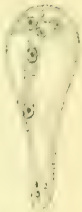

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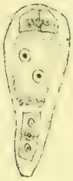

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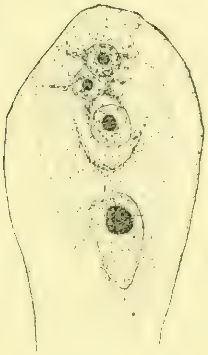

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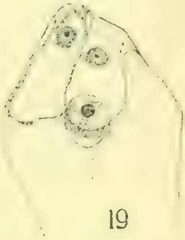

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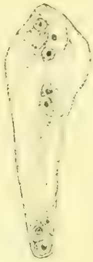

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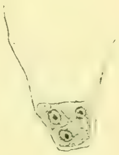

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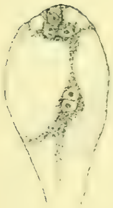

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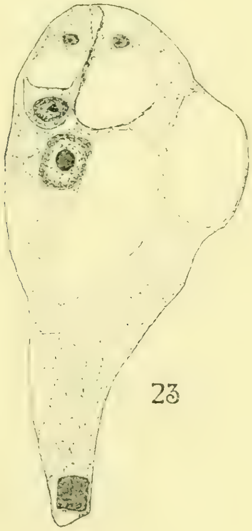

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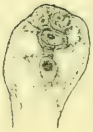

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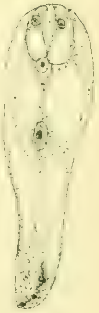

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PLATE X.

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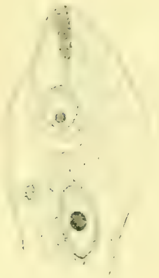

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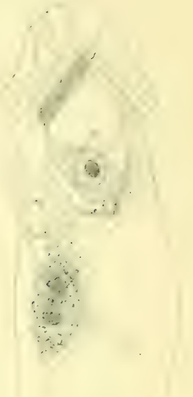

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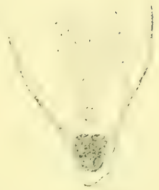

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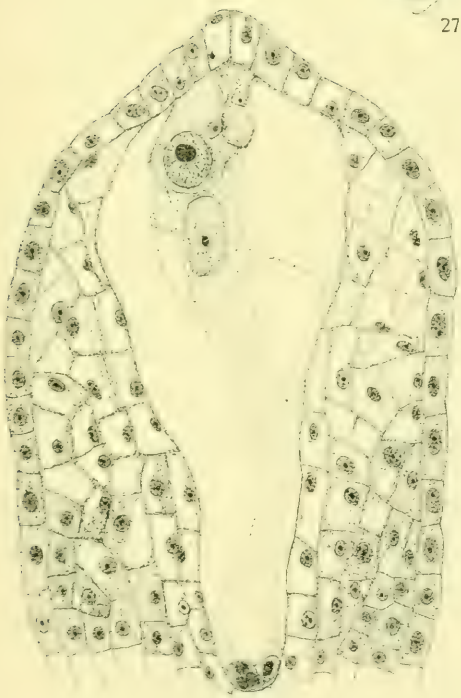

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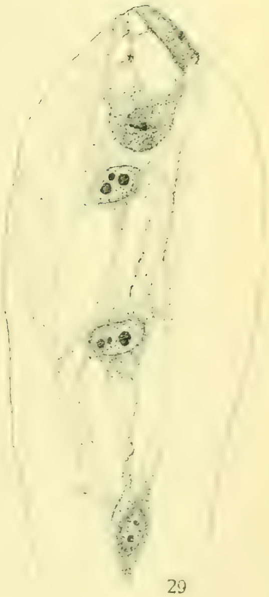

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PLATE XI.

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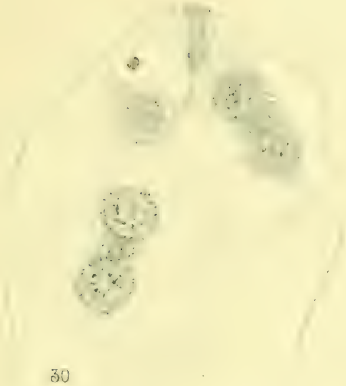

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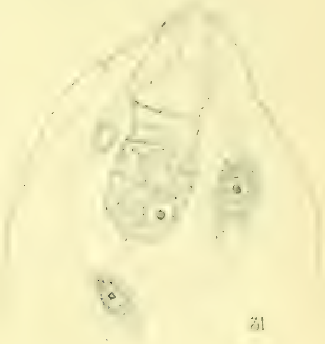

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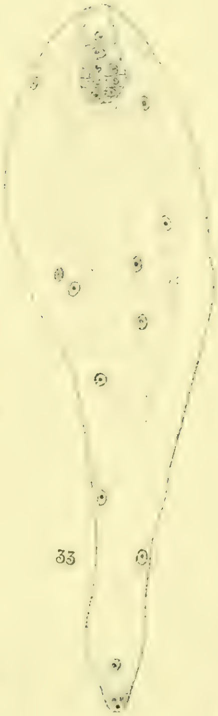

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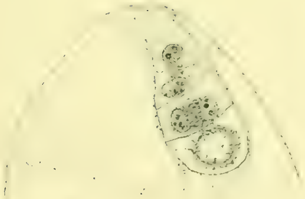

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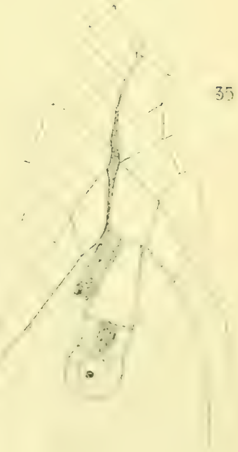

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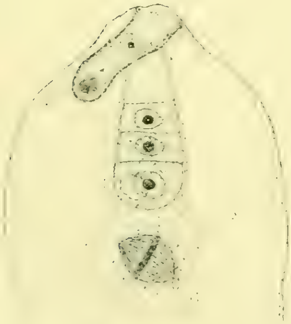

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PLATE XII.

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have degenerated, the fecundated egg is extending its cell wall upward to attach it to the anterior end of the sac and the definitive nucleus is dividing.

27. Posterior end of the sac whose anterior end is shown in 26. The antipodals are degenerating.

28. Embryo sac and surrounding tissue of the nucleus showing mutual relations of the two structures.

29. Anterior portion of embryo sac showing three of a probable four endosperm nuclei, pollen tube ruptured at the end and the egg dividing to form the two-celled embryo.

Plate XII.

30. Anterior end of an embryo sac somewhat younger than that figured in 29 and showing the discharged pollen tube, the egg apparently preparing to divide, and four endosperm nuclei with a spindle persisting between each pair.

31. Anterior end of embryo sac showing a five-celled embryo and three endosperm nuclei.

32. Young embryo in anterior end of embryo sac showing four newly formed nuclei and two persistent spindles.

33. Embryo sac of *Rumex salicifolius* showing a somewhat more advanced embryo, a larger number of endosperm nuclei and the antipodals still persisting.

34. Anterior end of embryo sac showing five-celled embryo, one of four observed dividing endosperm nuclei, and an undischarged pollen tube which entered the sac after the egg was fecundated.

35. Anterior end of embryo sac of *Rumex salicifolius* showing three-celled embryo, whose middle cell is dividing, and the persistent discharged pollen tube in the micropyle and extending into the sac.

XI. OBSERVATIONS ON GIGARTINA.

MARY E. OLSON.

The genus *Gigartina* is of wide distribution, especially in temperate latitudes. It is found both in the Atlantic and Pacific oceans as far north as the coast of Greenland and as far south as Cape Horn.

The material used in preparing this paper was collected in Puget Sound, at Channel Rocks, near Seattle, Washington, on August 3, 1897. It does not correspond exactly with any of the specific descriptions recorded. Indeed it has been with some reluctance that this plant has been included in *Gigartina*.

The material used for study in the preparation of this paper had been preserved in 75 per cent. alcohol, with the exception of some dried material which was studied in determining the color, size, shape and other external characters.

In the dried material the fronds appear thin and membranaceous and very brittle. The alcoholic material is leathery in texture and quite tough. The older fronds show a considerable increase in thickness over the younger ones, and are strongly *Calliblepharis*-like in appearance.

HABIT AND EXTERNAL APPEARANCE.

The fronds are reddish purple in color and occur at a depth of eight fathoms. Several or more fronds are generally found growing crowded together from united holdfasts. Such a group is seen in Fig. 1, Pl. 13.

The general outline of a frond whether branched or unbranched is typically cuneate. Fig. 3, Pl. 13 shows a good specimen of the unbranched type. When branched the general wedge-shaped outline is retained by a more or less regular, dichotomous form of branching, in which the branches spread and remain of considerable width. (Fig. 1, Pl. 13.)

Holdfast.—The holdfast is disc-like, and varies in size according to the number of plants springing from it. In an isolated individual (Fig. 3, Pl. 13) it is seen to be but little larger than the circumference of the base of the stipe. On the under side, by which it is attached to the substratum, it is seen to have a smooth surface, and two areas are clearly distinguishable in the alcoholic material used in this study; a central, nearly circular almost translucent area, and an outer apparently denser portion (Fig. 3, Pl. 13). When viewed from the upper side the significance of these areas is understood. If a large holdfast be examined, from which part of the fronds have been removed, the upper surface will be seen to be uneven and dotted with circular pits bordered by very distinct rims (Fig. 6, Pl. 13). On running the point of a needle through one of the translucent areas of the under side it is found to correspond with the pit of the upper side. A still more interesting demonstration is to pull away one of the fronds still attached to the holdfast. If this be done carefully it will be seen that a characteristic pit remains to mark the point of attachment of the stipe. An old holdfast is found to be covered with these scars, which are very perfect markings of the outline of the stipe at the point of attachment.

Stipe.—The stipe is a well-marked organ whose presence is more or less evident in all the plants, especially as they attain their mature size. Some of the members of the group in Fig. 1, Pl. 13, show that in the first stages the width of the frond varies but little from the base to the tip, so that a distinct stipe is scarcely distinguishable. Very soon, however, the upper portion of the frond begins to expand and a typical stipe becomes evident. Its outline just at the point of attachment to the holdfast is circular, but above this it becomes slightly compressed in one diameter so that its cross section appears oval or elliptical. The transition trom stipe to lamina is so gradual that no distinct demarcation can be detected between them. The shorter diameter becomes still shorter, and the longer one increases to the width of the frond till all appearance of the stipe has vanished and even the greater thickness at the center of the lamina merges so gradually into the thinner margins that it cannot be be said to be present as a midrib.

Lamina.—The lamina is seen to attain its greatest width at some little distance from the tip. If it is branched the division is dichotomous, though the lobes are often unequal in size, and occurs near the tip of the frond, so that there is no branching of the stipe. The margins present a more or less wavy, undulating outline. In fertile fronds the margins all along the upper part of the frond are prolonged into little leaf-like outgrowths bearing the cystocarps (Fig. 2, Pl. 13). These proliferations also occur on the surface of the frond and sometimes are scarely more than the stalk of the single cystocarps they bear. In many fertile fronds the surface is almost entirely covered with these outgrowths. As a rule they occur much more densely on one side than the other. Frequently they are found as simple small leaflets bearing no cystocarps. Their presence gives a look to the lamina quite suggestive of fruiting *Calliblepharis*.

INTERNAL ANATOMY.

Holdfast.—A section of the holdfast shows a very distinctive structure unlike anything seen elsewhere in the plant. The appearance of a section is seen in Fig. 9, Pl. 13, showing the outline of the pit or scar and the depression from which the stipe was removed. The cellular structure varies but little from the general type except in the transition zone from the holdfast to the stipe. Along the upper surface the cells are covered by a gelatinous envelope or cuticle of considerable thickness often 15 mic. deep (Fig. 10 a, Pl. 13). This, of course, in one of the scars extends only to the border of the pit as indicated in Fig. 9, Pl. 13. Some sections also show a similar layer on the lower side at joints (Fig. 9 b, Pl. 9), while the remainder of the lower surface shows a rough irregular margin of cells (Fig. 9 c, Pl. 13). The possible explanation suggests itself that the cuticle, when occurring on the lower side, appears at joints which, through some unevenness of the substratum, are not closely appressed to it and hence are left exposed as it were.

The tissue of the holdfast is characterized by cells having a quadrilateral outline as seen in zone "b" in the right-hand part of Fig. 10, Pl. 13. This general type becomes greatly modified in various regions. In the transition zone "c" (Fig. 10, Pl. 13), from the holdfast to the stipe, the angular outline of the cells disappears and they become more rounded and smaller in size. In all regions cells of irregular outline are frequently met with scattered among the cells of typical quadrilateral outline.

In general the cells are arranged in approximately regular rows extending vertically through the holdfast. This is more apparent outside the region of the pit than within. In passing from the holdfast proper to the stipe the character of the cells is seen to change, the outline becomes rounded, the cells smaller and the arrangement very irregular (Fig. 10 c, Pl. 13). On the upper side of this zone the cells become elongated and soon merge into the structure of the stipe (Fig. 10 d, Pl. 13). At the side, in the region where the surface of the holdfast passes to the surface of the stipe, an interesting curvature of the rows of cells of the holdfast is noticed (Fig. 10 e, Pl. 13). The upper cells of the holdfast gradually become smaller and merge into the outer cells of the stipe, so that at the periphery there is not so marked a change in the character of the cells as in the center. The central elongated cells of this stipe extend farther into the holdfast in the center than at the periphery of the stipe region. This is to be expected from the outline of the pits from which the stipe has been removed, and an examination of these pits under high power reveals the fact that none of the elongated stipe cells are present in the scar, showing that the separation zone when a stipe is pulled from a holdfast is at the region shown in Fig. 10, Pl. 13 at c, and curves upward at the sides, thereby forming the pit-like scar.

In many sections of stipe and holdfast the elongated cells are seen to extend much farther down than in the section of Fig. 10, Pl. 13, so that only one or two layers of holdfast cells lie between them and the lower surface.

In a few sections an interesting development of outgrowths on the lower surface was noticed. These occur below the stipe region and show the same cellular structure as the holdfast proper. They are apparently rhizoid-like growths (Fig. 10, Pl. 13).

The sections used were placed in an alcoholic solution of fuchsin for a few moments, then washed with alcohol and mounted in glycerine jelly. The stain failed to bring out any cell contents and to all appearances the cells are empty.

Stipe and Lamina.—The structure of the stipe and lamina is very similar, the chief difference being that in the former the cells are of somewhat smaller diameter.

The upright portion of the plant may be divided, anatomically, into two fairly distinct portions: the pith, consisting of the larger, apparently empty cells and the cortex, of smaller cells containing the chromatophores. Because of this difference in the cells the sections for the structure of the stipe and lamina show the outlines of the cell wall in the pith, but in nearly all the sections examined the cell walls of the cortex could not be distinguished, and it is the outline of the cell contents that is represented in such sections.

The inner portion or pith consists of elongated, cylindrical cells, united into loosely interwoven filaments, extending principally in the direction of the long axis of the frond. The union between cells is so irregular that often the filamentous arrangement is scarcely recognizable. Surrounding this pith region, which is of compressed cylindrical contour in the stipe, is the cortex, which consists of much smaller cells, arranged in radiating rows, more or less regular, perpendicular to the surface of the frond.

Pith.—The transverse sections of both stipe and lamina show the cross-sectional outline of the pith cells to be more or less circular with considerable space between the cells (Figs. 12 and 13, Pl. 13). In the lamina portions of a filament are often found running through the section. The outlines of the pith cells in both lamina and stipe show an area of larger cells just within the cortex, passing inward to a central portion of smaller diameter (Fig. 11, Pl. 13). Within the pith itself there is considerable variation in the size of the cells, showing that smaller filaments anastomose with the larger ones.

The average size of the cells is from 100 to 170 mic. long by 17 to 33 mic. wide. The most interesting feature of the pith is the presence of protoplasmic pits connecting the cells. These occur not only in the end walls, but also in the lateral walls, as seen in Fig. 11, Pl. 12. By these connections, as well as by lateral pressure in some cases, the cylindrical outline of the cells becomes variously modified.

Communication of adjacent cells of the pith region is thus completely established. The significance of this will be more clearly seen as the physiological importance of this area is discussed. These pits were first discovered by staining with hæmatoxylin. A more careful trial of different stains showed that these pits always take the stain more deeply than any other part, either cell contents or cell wall. Both methyl violet and fuchsin produced good results. An alcoholic solution of the stain was used.

A study of these pits showed them to be of the form of small plates or rings, apparently one in each of the two adjacent cells (Figs. 11 and 13, Pl. 9). When seen edgewise they appear as two small plates narrower than the width of the cell wall, so that the inner line of the cell wall appears to curve out to meet them. Often the entire outline of one ring may be seen and only part of the other, which apparently lies beneath it. Again the section will lie so as to show both rings.

Some sections, especially with the methyl violet, showed a faint outline of cell contents just within the wall and in all cases extending close up to the rings or pits. Careful observations of this sort led to the opinion that these connecting pits must be of the nature of the protoplasmic cell contents rather than the cell wall. Schmitz confirms this opinion. Unfortunately the writer did not have access to Schmitz's original article, but in George Murray's *Introduction to the study of Seaweeds*, 1895, in the chapter on Rhodophyceæ (which he states is based upon Schmitz's papers) the following is found (p. 201): "The plates stand in direct connection with the protoplasm lining the cell wall and are, in fact, so coherent with it that they may be regarded as transformed or rather differentiated protoplasm locally covering the pit. However it is probable that a thin layer of protoplasm covers them in turn."

All observations have gone to show that there is an intimate protoplasmic connection between the contents of neighboring cells. Zimmermann's Botanical Microtechnique was consulted as to re-agents for testing these rings.

The use of sulphuric acid and a mixture of iodine and potassium iodide is recommended for cellulose walls giving a blue color. This was used, but neither the cell walls nor the pits showed any trace of blue staining. Cuprammonia was also tried, but with no success. Some interesting results were obtained, however, with the use of sulphuric acid. The sections were first stained and then treated with the acid. Although the acid at once destroyed the original color it was found better results were obtained than without first staining. A trial was then made as to the strength of acid which would give most satisfactory results, and it was found that treating sections prepared as before described, with a 50 to 60 per cent. solution of the acid produces at first no apparent effect beyond a slight swelling of the cell wall. The sections were left mounted in the acid, and after twenty-four hours re-examined. It was then found that the cell walls were all dissolved and only the rings remained (Fig. 17, Pl. 14). This leads to the conclusion that the rings are not of the same composition as the cell wall.

The pith of the cystocarpic proliferations of the frond shows a marked difference from that of the vegetative portion (Fig. 18, Pl. 14). The cells have become very irregular in outline and are so anastomosed and interwoven as to form a network which becomes more and more dense in passing from the stalk to the pericarp proper. Here, as well as in the cortex, the cell contents have a dense granular appearance, and the cell walls appear only very faintly, if at all. In most sections stained as in the vegetative part they cannot be distinguished. This is true also of the protoplasmic pits, though it is evident there is close communication throughout. From one or two unusually clear sections it was ascertained, however, that the rings are present, but are very small. The cells in this region measure from 25 to 37 mic. long by 2.5 to 7 mic. wide.

Cortex.—The transition from the pith to the cortex is somewhat abrupt. In longitudinal sections the pith cells are seen to decrease in length until in the four or five outermost rows the outline of the cells is spherical or slightly oblong. In the transition zone, or the inner part of the cortex, they measure from 5 to 12 mic. along either diameter.

In the outermost layers of smallest cells, measuring from 2.5 to 5 mic. in diameter, the cell contents are very dense and the cells are apparently imbedded in a gelatinous matrix from which it is impossible to distinguish their walls. In one section, however, the writer was able to make out faint outlines of the walls, but it is difficult to represent them and maintain the proportional thickness of the wall (Fig. 11, Pl. 13).

The cortex cells are seen to lie in communication also, but only along the radial lines of the thallus. The cells are so small no rings can be distinguished, but protoplasmic threads are seen running from cell to cell (Fig. 13, Pl. 13). There are no lateral protoplasmic connections between cells. A surface view of the thallus shows a somewhat regular arrangement of the end cells of these radial rows. They appear as a rule in groups of two or occasionally three, surrounded by the gelatinous matrix (Fig. 14, Pl. 14). If the sections be placed in water this swells rapidly, as do also the cell walls. The walls often increase to three or four times their width, as seen in alcoholic material, and a stratification of the walls becomes evident (Fig. 16, Pl. 14).

REPRODUCTIVE ORGANS.

Cystocarps.—The material studied was too far advanced to show antheridia or the development of the cystocarp.

The cystocarps are found scattered very abundantly along the margin and over the surfaces of the fertile fronds. As a rule they are much more abundant upon one surface than the other.

They are borne in leaf-like proliferations of the frond and are usually more or less distinctly stalked, though often they are nearly sessile. Fig. 4 shows one of these leaf-like outgrowths bearing no less than nine cystocarps. Generally the number is smaller, from two to four (Fig. 5, Pl. 13). The larger leaflets, with a larger number of cystocarps, are usually found along the margin.

In form the cystocarps are subglobose with a marked indentation at the apex which seems to indicate a distinct carpostome, but in the large number of sections observed no opening could be detected. The nearest approach to it was seen in the section represented in Fig. 19, Pl. 10, but even here there is no sign of a true pore or even of a rupture, so that evidently the cystocarp is closed. From the uniform closure of the cystocarp it is difficult to include the plant in question with *Gigartina*. The structure of the cystocarp regions of the thallus shows the same two general areas described for the stipe and lamina with the modification of the inner region or pith described above. The spores are developed within the central region, the cortex and outer part of the pith forming a true pericarp. Except at the apex both areas surround the central mass of spores. Here it is covered only by the cortex.

A peculiar structure observed was one in which the surface of the thallus was only slightly raised to indicate its location, and numerous long filaments were seen with their tips protruding slightly from the surface (Fig. 18, Pl. 14). The section was stained with fuchsin and the clear filaments were sharply distinguishable from the other cells with their granular contents. They measured 150 mic. in length.

There was some little doubt as to what should be the interpretation of the section represented in Fig. 18, Pl. 14. The pith cells have the appearance characteristic of the cystocarp region. A comparison with figures in which trichogynes are represented shows but slight similarity in appearance. The pericarp consists of the two layers found in the lamina and stipe. The outer small cells containing chromatophores pass somewhat abruptly to the cells of the interior (Fig. 21, Pl. 14), which are elongated and connected to form a more or less dense net-work. In most cases the transverse connecting cells are more numerous than in Fig. 21, so that the pericarp presents the reticulated appearance of the tissue in Fig. 19. Very frequently, however, the cells show much lateral crowding in the pericarp.

The cystocarp is compound and the spores are aggregated into distinct groups (Fig. 19, Pl. 14). This is clearly seen in all but the oldest cystocarps and even here a carefully cut section shows it. These groups are separated from each other by large, empty cells, with smaller cells of the same character extending between them (Fig. 20, Pl. 14). This is brought out very clearly by staining the section with iodine and then washing in water.

The carpospores are more or less oval in shape, often somewhat angular. They measure from 12 to 15 mic. along one diameter by 10 to 12 mic. along the other.

The normal cystocarps measure from 1 to 2 mm. in diameter, but it was noticed that frequently some were met with from two to three times as large as the ordinary ones, measuring 2.5 to 3.5 mm. On examination it was discovered that the fronds of another small alga were always found upon these large cystocarps. Several specimens were studied and it was found that there was evidently more than one species infecting them. The largest one discovered is represented in Fig. 7 a, Pl. 13. It appears to emerge directly from the apical depression of the cystocarp. A longitudinal section through the cystocarp shows the parasite or epiphyte to consist of an axial cylinder of large cells with protoplasmic connections between adjacent walls. Most externally is a region of quadrilateral cells larger than the corresponding cells of the host arranged quite irregularly, and between this and the central cylinder a region of long filamentous cells, and it is these which are seen to penetrate the pith of the pericarp (Fig. 22, Pl. 14). They can be traced to the central spore-bearing area, where they apparently curve outward and follow along the side a short distance. They are distinguishable from the granular cells of the pericarp by their clear appearance.

In most cases the infecting plant was found to be a smaller one, represented in b Fig. 7, Pl. 13. It consists of simple or branched filaments of oblong cells, but its entrance into the tissues of the pericarp could not be detected. Its presence is evidently the cause of the enlargement of the cystocarp, however. Except in cases where the parasite can be seen within the tissues of the cystocarp no difference except size can be observed between the infested organs and the normal ones.

Nemathecia.—These were found upon only one frond in the alcoholic material at command, but in this they were abundantly distributed on both sides of the frond. They appear in surface view as wart-like projections which can be distinguished with the naked eye by their slightly lighter color (Fig. 8, Pl. 13). (It must be remembered that this description applies to alcoholic material.)

A section of the frond shows many interesting features. The filaments of the internal pith area are even more loosely anastomosed than in the vegetative part of the frond and show large intercellular spaces. In this central area large, dark bodies the size of spores were discovered scattered very abundantly among the filaments (Fig. 24 e, Pl. 14). These could easily be seen from the surface, showing through the external area of cortex cells, and even appear to the naked eye as tiny black dots. Upon examination they were found to be of a dark green color and apparently unicellular. They are evidently internal parasites, but no connection between them and the nemathecia could be discovered, though it was earnestly sought, inasmuch as Schmitz, in his article "Die Gattung Actinococcus Kutz,"* ascribes the nemathecia of *Phyllophora brodiæi* and *P. interrupta* to the parasite Actinococcus.

Outside the central filaments is an area of approximately spherical cells, which decrease gradually in size toward the exterior. They exhibit a characteristic arrangement, *i. e.*, from a single basal cell two and sometimes three rows diverge toward the surface. The outer layer is covered by a thick gelatinous cuticle (Fig. 24, Pl. 14). The tetraspores are evidently produced from the cells just outside the central filaments and are formed in irregular masses just below the surface.

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* Schmitz. Flora. 77: 367. 1893.

In many places where there is almost no elevation of the surface a small group of tetraspores is distinctly seen in section. Staining with iodine brings out the distinction between tetraspores and the surrounding cells very clearly.

A peculiar feature of the nemathecia is the pore-like break in the cuticle just above the group of spores. This was seen in even the smallest nemathecia, and in the larger ones several were often present. A full-grown nemathecium rises from 25–37 mic. above the level of the thallus, and an irregularity in the arrangement of the cortex cells is noticeable at the apex, suggesting a rupture as a result of the crowding upward of the spores. The spores measure 12–20 mic. by 10–15 mic.

Wille* makes a physiological distinction between the pith and cortex regions, considering the former as conducting tissue and the latter as assimilative. Some interesting results were brought out by iodine staining in connection with this view.

Sections of the holdfast, stipe, lamina, cystocarp region and nemathecia were placed in an iodine solution for half an hour, then washed with water, with the following results: The holdfast simply shows a general yellowish staining of the cell walls, showing there is no starch present in that region, as would be expected from its evident mechanical function. The stipe likewise showed a slight yellowish staining of the walls, but no cell contents in accordance with its function as a supporting and conducting area.

In the lamina the sections used were longitudinal ones. The central elongated cells remained colorless; in the inner cortex cells marking the transition in shape from the central to the small peripheral cells the contents stained a deep purple, indicating the presence of starch. The four or five outer rows showed the cell contents stained yellowish brown. These are the cells containing chromatophores. These results suggest a confirmation of Müller's interpretation of the physiological significance of this area, inasmuch as they are evidently concerned with the food supply.

In the cystocarp region the outer layers of cells containing rhodoplasts stain yellowish brown as in the lamina; the rest of the pericarp and the spores stain a deep violet, but the thin-walled cells separating the groups of spores stain yellow. This brings out the structure of the central spore region better than any of the other stains used.

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* Wille, N. Nova Acta Acad. Leop.-Carol. Nat. Cur. 52: 49–100. *pl. 3–8.* 1897.

In the nemathecia the tetraspores stain a deep violet, as also do the contents of the central filaments just below the spores. The rest of the central filaments remain unaffected and the outer cells stain yellowish brown.

SPECIFIC DESCRIPTION.

Gigartina sp. und.—Fronds purplish-red, distinctly caulescent, several often springing from the same disc-like holdfast; 18–28 cm. long by 7–10 cm. wide. Stipe somewhat compressed, 3.5 to 5 mm. wide by 2–3 mm. thick, gradually widening into the typically cuneate lamina. Young fronds often entire, older ones sparingly branched, branches expanded, never linear or lanceolate. Cystocarps compound, closed, more or less stalked, several generally occurring crowded together on the same proliferation; enclosed within a pericarp; 1–2.5 mm. in diameter; carpospores numerous, crowded together in more or less definite groups, oval, 12–15 mic. long by 10–12 mic. wide. Tetraspores produced in nemathecia, on both sides of the frond; nemathecia wart-like, rising 25–37 mic. above the level of the thallus. Tetraspores oval, more or less angular, 12–20 mic. long by 5–10 mic. wide.

METHODS.

Part of the sections used were cut with the freezing microtome, the rest by hand. The material used had been preserved in 75 per cent. alcohol. The effect of imbedding in gelatine prepared according to Osterhout's directions was tested. The portions to be sectioned were cut in* pieces .5 cm. long and about the same width and placed in the gelatine. This was left for twenty-four hours to allow the gelatine to penetrate the tissues, then removed and placed in a gum arabic solution on the freezing chamber. After several trials it was found that sections introduced directly into the gum arabic without embedding were as satisfactory as by the longer process.

Staining.—At first water solutions of the stains were used, but it was found that this caused the tissues to swell to such an extent that cells often presented a very unnatural appearance. For example, a cross section of the stipe was obtained in which the cell lumen appeared irregulary star-shaped or was nearly obliterated (Fig. 16, Pl. 14). This was then abandoned and alcoholic solutions were used. Both staining the sections and the material in toto were tried. In the latter method, if the material was to be imbedded, it was first stained. If the stain is sufficiently diluted, and the sections are allowed to stand in it from ten minutes to half an hour, the results are quite as satisfactory as staining in toto, for in the latter method often the stain fails to penetrate the material completely.

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* Osterhout. Bot. Gaz. **21**: 195–201. 1896.

The stains employed were hæmatoxylin, anilin blue, methyl blue, carmine, methyl violet, fuchsin and safranin. Hæmatoxylin stains both cell wall and contents, but not clearly enough; it was found very unsatisfactory. Anilin blue and carmine hardly affected the tissues. Methyl blue and safranin proved good for the gelatinous sheath. Methyl violet and fuchsin gave the most satisfactory results. They stain both the cell walls and protoplasmic contents, but the latter more deeply. These two stains, and especially fuchsin, were used for all the work.

The sections were at first taken from the knife and placed in glycerine, transferring gradually from 20 per cent. to absolute, but the glycerine was found to swell the cell walls to a considerable extent and was abandoned.

The most satisfactory method and the one employed in all the latter part of the work was as follows: The alcoholic material was placed directly in the gum arabic solution on the freezing chamber, transferred from the knife to the alcoholic solution of the stain and mounted in it. When the staining was completed, usually after a few moments, the sections were washed in alcohol. This was then evaporated and, without allowing the sections to become dry, glycerine jelly was added, making a permanent mount.

BIBLIOGRAPHY.

Jönsson, B. Beiträge zur Kenntniss des Dickenzuwachses der Rhodophyceen. (Bot. Zeit. 50: 181. 1892.) (Bot. Jahresb. 19: 120–121. 1894.) Lunds Univers. Arskr. 27: 41. *2 pl.* 1890–91.

Wille, N. Beitrag zur Entwicklungsgeschichte der physiologischen Gewebesysteme bei einigen Florideen. Nova Acta Acad. Leop.-Carol. 52: 49–100. *pl. 3–8.* 1887. (Bot. Jahresb. 16: 754. 1891.)

Osterhout, W. J. V. A Simple Freezing Device. Bot. Gaz. 21: 195–201. 1896.

Schmitz, F. Die Gattung Actinococcus Kütz. Flora. 77: 367–418. *pl. 7.* 1893.

Moore, S. Le M. Studies in Vegetable Biology.—I. Observations on the Continuity of Protoplasm. Journ. Linn. Soc. 21 : 595–621. *pl. 19–21.* 1886.

EXPLANATION OF FIGURES IN PLATES XIII. AND XIV.

All drawings were made from material preserved in alcohol.

Fig. 1. Group of fronds springing from a common holdfast. One-half natural size.

Fig. 2. Upper portion of fertile frond showing marginal and surface proliferations with cystocarps produced upon them. One-half natural size.

Fig. 3. Young frond showing typical shape and single holdfast. One-half natural size.

Fig. 4. Small leaflet with cystocarps. x 4.5.

Fig. 5. Four cystocarps on a small stalk-like proliferation. x 4.5.

Fig. 6. Surface view of holdfast showing scars. x 4.5.

Fig. 7. Cystocarps infected by a parasite. x 5.

Fig. 8. Surface view of nemathecia. x 5.

Fig. 9. Section through a scar of the holdfast: *a*, layer of cuticle on upper surface; *b*, region of the lower surface covered with cuticle; *c*, rough broken lower surface. x 5.

Fig. 10. Section through the holdfast with rhizoid-like outgrowth from the lower surface. A portion of the tissue is omitted in the center, as it issimply a continuation of that represented on either side. Toward the left the drawing stops in the stipe region. On the right the transition from the stipe to the holdfast is shown: *a*, cuticle of upper surface; *b*, region showing cellular structure characteristic of the holdfast; *c*, cellular structure marking transition from tissue of holdfast to that of stipe; *d*, beginning of tissue of the stipe; *e*, curvature of cells at juncture of stipe and holdfast. x 300.

Fig. 11. Longitudinal section of the lamina: *a*, cortex; *b*, outer region of pith showing larger pith cells; *c*, inner region of pith with smaller cells. x 300.

Fig. 12. Cross section of stipe: *a*, cortex; *b*, larger celled pith; *c*, smaller celled pith. x 300.

Fig. 13. Cross section of the lamina showing many pith cells connected by pits and cortex cells connected by protoplasmic threads. x 300.

Fig. 14. Surface view of thallus. x 300.

Fig. 15. Outline of cross section of stipe showing cortex and pith areas. x 4.5.

Fig. 16. Pith cells of lamina stained with methyl violet and mounted in glycerine. Cell wall is much swollen and one shows stratification. x 300.

Fig. 17. Effect of sulphuric acid on cell wall and pits; *a*, pith cells treated for ten to fifteen minutes in 50 per cent. solution; *b*, pits as seen twenty-four hours after treating the section with the acid. The walls have been entirely dissolved. x 300.

Fig. 18. Cluster of filaments. x 300.

Fig. 19. Longitudinal section through a cystocarp. x 85.

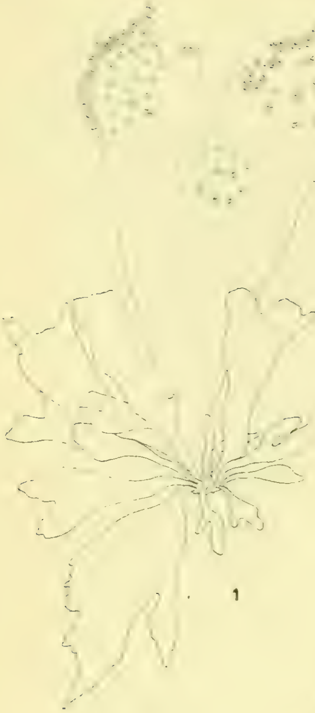
Fig. 20. Group of spores from cystocarp with thin-walled cells separating them. x 300.

Fig. 21. Longitudinal section through the pericarp: *a*, cortex; *b*, pith; *c*, spores. x 300.

Fig. 22. Longitudinal section through an infested cystocarp. The upper left-hand portion shows the manner in which the parasite penetrates the host. x 56.

Fig. 23. Portion of the same region enlarged showing to the left the tissues of the host pericarp and to the right the long filamentous cells of the parasite. x 300.

Fig. 24. Section through frond producing nemathecia. On the upper surface is a mature nemathecium, on the lower surface two two younger ones: *a*, gelatinous cuticle; *b*. pore-like break in cuticle; *c*, cortex cells; *d*, cells from which tetraspores are produced; *e*, parasite; *f*, pith filaments. x 300.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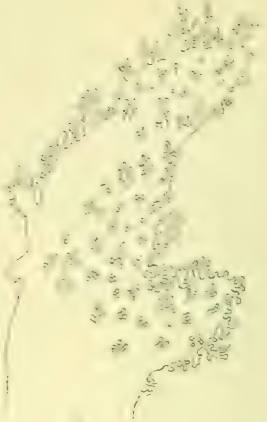
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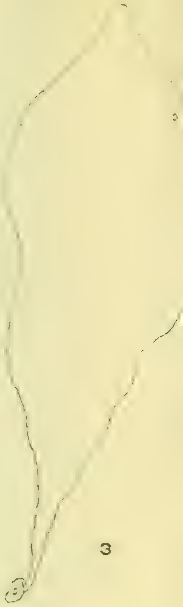
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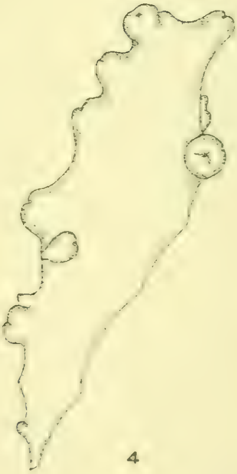
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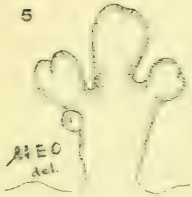
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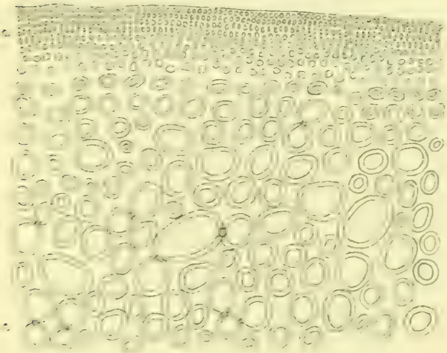
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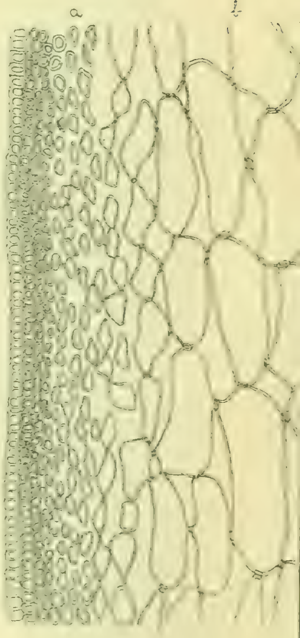

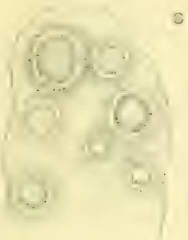
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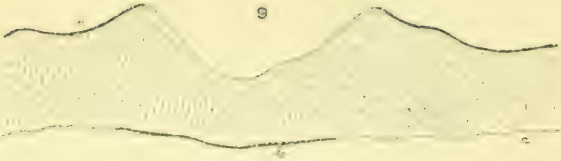
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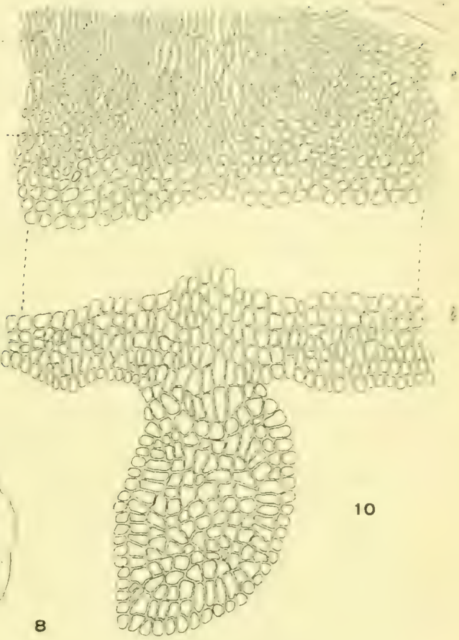
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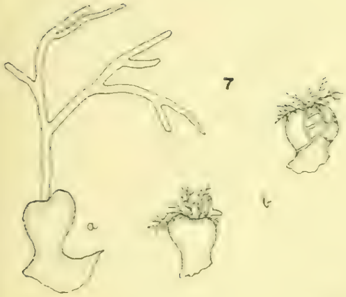
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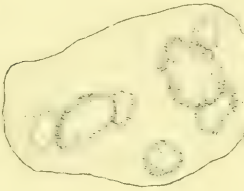
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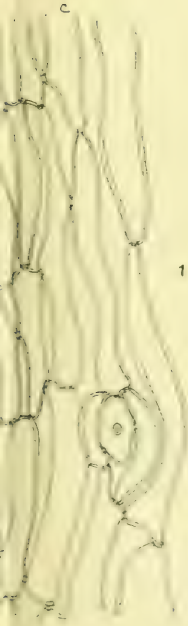
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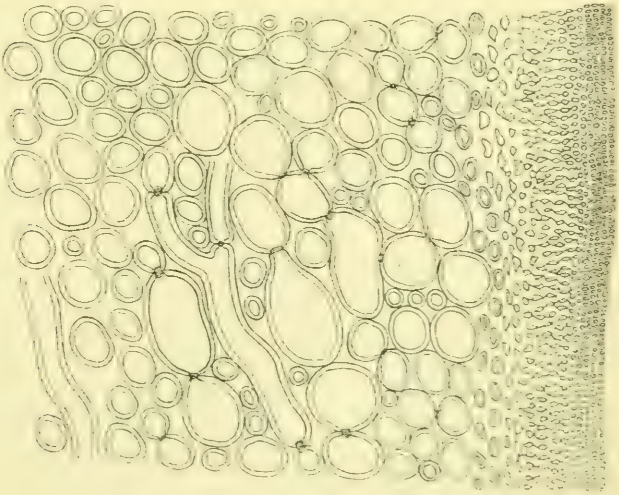
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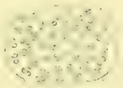

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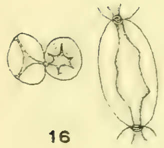

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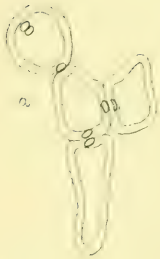

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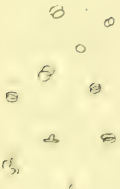

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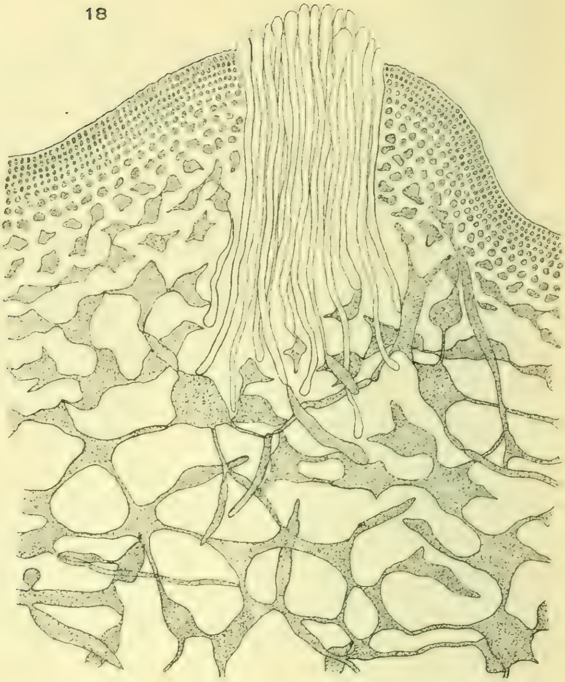

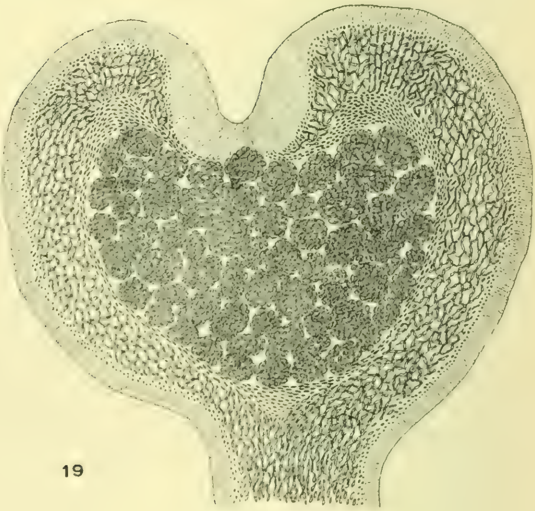

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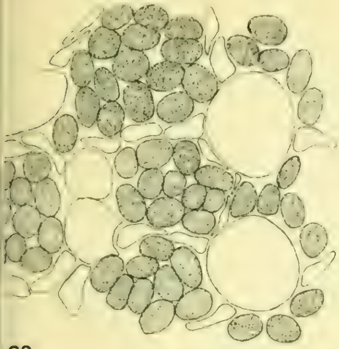

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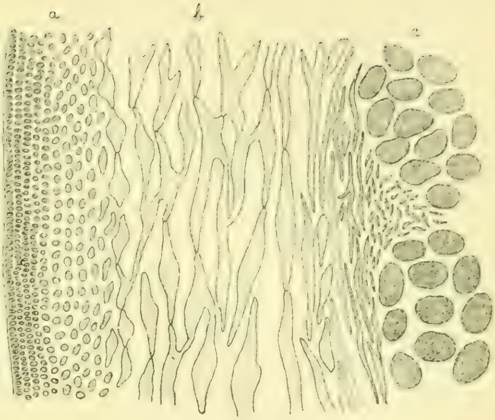

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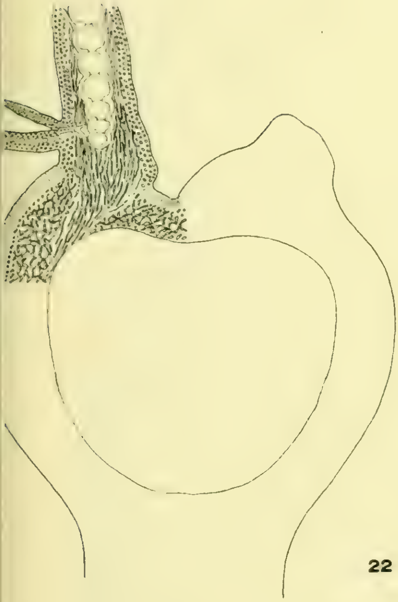

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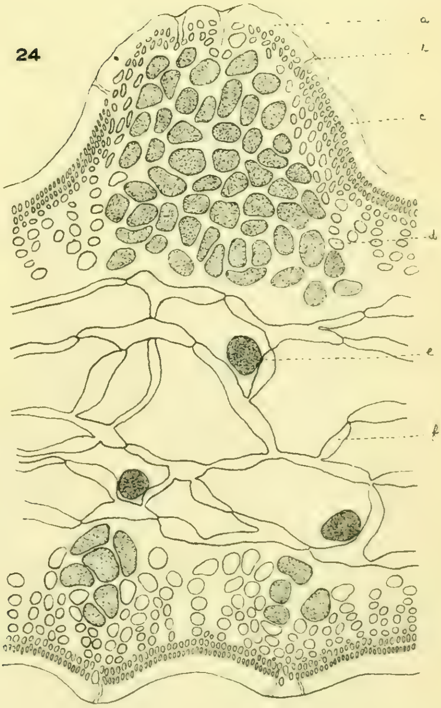

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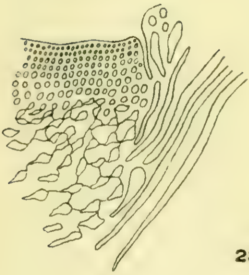

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XII. SEED DISSEMINATION AND DISTRIBUTION OF RAZOUMOFSKYA ROBUSTA (Engelm.) Kuntze.*

D. T. MacDougal.

The branches of the bull pine (*Pinus ponderosa scopulorum*), of the southwestern United States, offer suitable conditions of nourishment for the growth of *Razoumofskya robusta*, a parasite belonging to the Loranthaceæ. Some of the members of this family, such as the mistletoe (*Phoradendron flavescens*), which live on deciduous trees in temperate latitudes, are furnished with a fair amount of chlorophyll. These forms are able to carry on more or less food-formation during the warmer portions of the season in which the deciduous hosts lack leaves. *Razoumofskya*, however, fastens on an evergreen conifer, and hence has no such need or use for chlorophyll. It is, therefore, furnished with this substance in minute quantity only, and its leaves are reduced to mere bracts. It is diœcious, and the aërial shoots of both kinds may appear in close contiguity on the same branch of the host or be separated some distance. The shoots start up from the submerged rhizomes in the latter part of April or early in May, the flowers maturing in June and the seeds in August. After the dispersal of the seeds the aërial portion of the plant dies away, leaving only the haustorial rhizomes buried in the tissues of the host plant. With the opening of the next season shoots are produced as before.

The submerged portion of the parasite penetrates the branches of the host long distances longitudinally, and where aërial shoots are given off the tissues of the host show abnormal structures, the branches undergoing enlargement, while the development of the nearest buds is variously checked and altered. The distortion is magnified with age, and old trees exhibit the most grotesque malformations. The writer has seen trees a meter in height infected, and the size of the older branches bearing the parasite is such as to justify the statement that they may live ten to twenty years after the parasite has fastened upon them. A common type of structure resulting from the attachment of the parasite to the pine consists of an old branch bent downward, from the infected tip of which numbers of smaller branches stand erect, forming a coarse "witch's broom" (See Plate XVI.).

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*An abstract of this paper was read before the Botanical Club of the A.A.A.S. at Boston, August 25, 1898.

Perhaps the most interesting facts in connnection with the history of *Razoumofskya*, are those which concern the distribution of the seeds. The single-seeded berries are borne on short stalks curved semi-circularly, from which they are easily detached when ripe. The berry is joined to the stalk by a scission layer, which is ruptured by the slightest touch or may be burst away by the action of forces set up in the berry, which also expel the seed. The shooting of the seeds from the berry has been known for many years, and a note of the fact has found place in American text-books of systematic botany, but it has failed of wider recognition. Engler and Prantl remark concerning the seeds of the Loranthaceæ: "The stickiness enables some seeds falling from branch to branch to become attached; on the other hand, birds crush the fruits and discard the seed, which is surrounded by a viscid layer." (Naturlichen Pflanzenfamilien. Theil III.) Kerner says: "The dissemination of the European mistletoe is effected as in all Loranthaceæ through the agency of birds, thrushes in particular, which feed upon the berries and deposit the undigested seeds with their excrement upon the branches of trees." (Nat. Hist. of Plants, I: 205, 1894.) Keeble, the most recent observer who has published upon the Loranthaceæ, says: "The berry-like fruits of the Loranths are technically speaking indehiscent; yet owing partly to growth of the embryo, partly to weakening of the fruit wall in some species, this latter becomes ruptured on the ripening of the fruits, *e. g.*, *Loranthus neelgherrensis L. cuneatus;* in others a very slight pressure is sufficient to cause the complete extrusion of the seed, sometimes basally, sometimes apically. In all cases the seed slips out, but in *Viscum orientale* Willd., a gentle pressure will cause the fruit wall to crack and the seed to be jerked out." (Observations on the Loranthaceæ of Ceylon, Trans. Linn. Soc. Lond. 2nd Ser. Bot. 5: Pt. 3, p. 97, 1896.)

In view of the above statements it is safe to conclude that *Razoumofskya* is the only Loranth furnished with a mechanism for the expulsion of the seeds from the berries without the intervention or coöperation of outside factors. The expulsory mechanism is best seen in a longitudinal section of the berry. The base of the berry is joined to the stalk by a scission layer several cells in thickness. The outer coat is firm and smooth, and is composed of an epidermal layer with the outer wall extremely heavy and cuticularized. Beneath the epidermis is a mass of parenchymatous tissues, the outer portion of which is slightly palisaded and containing chlorophyll, the inner layer showing only starches and sugars. Immediately internal is the fibrovascular framework which fuses at the apex in a solid mass of mechanical tissue. Lying inside the fibrovascular strands, and continuous with the parenchymatous tissue external to it is also a mass of similar thin-walled elements of ovoid or cylindrical form rich in carbohydrates. These cells have their axes at right angles to the surface of the berry. The second layer internal to the fibrovascular tissue is the expulsory layer, consisting of very long thin-walled cylindrical tubes with their axes parallel to the long axis of the berry at the apex of the seed or variously inclined from this position according to the location, but all so arranged that their longitudinal expansion would tend to force the seed out of the mouth of the sac formed by the berry. Immediately coating the seed is a layer of globoid cells with thick mucilaginous contents. The seed has the form of a modern rifle bullet, conical at the basal end and truncate at the apical end, with a general cylindrical outline. The scission layer appears to cut into the mucilaginous layer or at least very nearly so in the mature berry. During the ripening period the contents of the expulsory layer undergo such chemical changes as to give the contents a very high isotonic coefficient. The consequent osmotic attraction of water into this layer sets up a turgescence which could not be measured, but which probably amounted to many atmospheres. The steady increase of the turgidity of the expulsory layer brings the tension to the breaking strain of the scission layer, and its sudden and complete rupture permits the full force of the pressure to act upon the seed, sending it to a distance of two or three meters. The entire arrangement is that of a mortar cannon.

The muzzle of the gun is sealed by the stalk, and the charge amounts to several atmospheres, which is allowed to act upon the seed when the muzzle is freed. The firing of this unique gun may result from the overcoming of the resistance of the restraining layer at the muzzle, or this event may be precipitated by any force from the outside which would result in the disturbance of the scission layer. One may stand under a pine tree on a quiet morning and hear the sharp click accompanying the expulsion of the seed from the berries at irregular intervals. If the branches are jarred or shaken, however, the irregular explosions give way to fusillades by which nearly all of the berries on a plant will be set in action at once.

The expulsion of the seed occurs as soon as the berry has broken loose from the stalk, and as these berries were originally in all positions the seeds are sent out in all directions. The mucilage adhering to the seed causes its attachment to the branches or other bodies it may strike. In this manner dissemination is effected throughout a cylindrical space about seven meters in diameter and extending downward to the ground. The only localities which offer suitable conditions for the germination and growth of the seeds, however, are the tips of branches or the shoots of young trees underneath. It is to be seen that no animals are to be found in the habitat of the parasite which would in ordinary usage carry the seeds to these locations. The only part, therefore, that animals play in the dissemination of the seeds would be in causing the discharge of the berries, a matter of no direct value, since they are capable of quite as efficient action independently. The berry of *Razoumofskya* is, therefore, to be classed as a sling fruit, and is probably the only one of this class from the United States which has been described, though many doubtless exist.

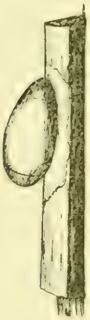

FIG. I.

Seed of *Razoumofskya* adhering to pine leaf.

A second point of interest in this plant consists of a fact bearing upon its local distribution. During the course of some recent field work in northern Arizona the writer found that *Razoumofskya* was most successful in its attacks on the pine trees along the rims of cañons or along the brows of hills or margins of mesas. A study of the meteorological conditions shows that this method of distribution has a direct connection with the vertical movements of the air.

As the air resting on lowlands in cañons or valleys is warmed by radiation during the time of exposure to the sun's rays, it rises and expands. During the ascent some heat is converted into the work necessary in expansion, causing a cooling of one degree Fahrenheit for every one hundred and eighty-eight feet of elevation. The decrease in temperature lowers the dew point or increases the relative humidity, a matter of very great importance to germinating seeds and transpiring leaves. *Razoumofskya* is especially abundant, precisely at the places where the effect of the ascending humid currents of air is greatest, along the margins of hills and mesas and the rims of cañons. This is very noticeable along the Grand Cañon of the Colorado river, in the Coconino Forest reserve, where the air rising more than a vertical kilometer from the river bed pours across the pine-covered mesa at a much lower temperature and very much nearer the dew point than the body of air which it replaces. In its rise it has lost heat at the normal adiabatic rate to the amount of about twenty-five degrees F., and has undergone a great variation with respect to the dew point. As a consequence of the increased humidity favorable to germination, the pines near the rim of the cañon are most thickly infested with the parasite over a belt one to four or five kilometers in width running parallel to the margin. One may walk through the forest and note the decreasing abundance of *Razoumofskya* as the distance from the cañon increases.

In recapitulation of the facts adduced in this note it is to be said that the berries of *Razoumofskya* are to be classed as sling fruits, the only one from North America hitherto described, and that this genus is the only one of the Loranthaceæ furnished with means of seed-dissemination independent of gravity and animals. The writer also believes that he is justified in announcing the discovery of the influence of vertical air-currents upon the distribution of plants, and that this factor must be taken into account in the consideration of the boundaries of zones in mountainous regions or those with irregular topography.

EXPLANATION OF PLATES.

Plate XV. D. Staminate plants of *Razoumofskya*. B. Pistillate plants with mature berries. The distortion of the branch of the host is plainly shown.

Plate XVI. A. *Pinus ponderosa* dying from the effects of the parasite, photograph of a specimen growing on the extreme edge of the rim of the Grand Cañon of the Colorado, June, 1898. C. Specimen of *Pinus ponderosa* showing drooping of branches attacked by *Razoumofskya*.

PLATE XV

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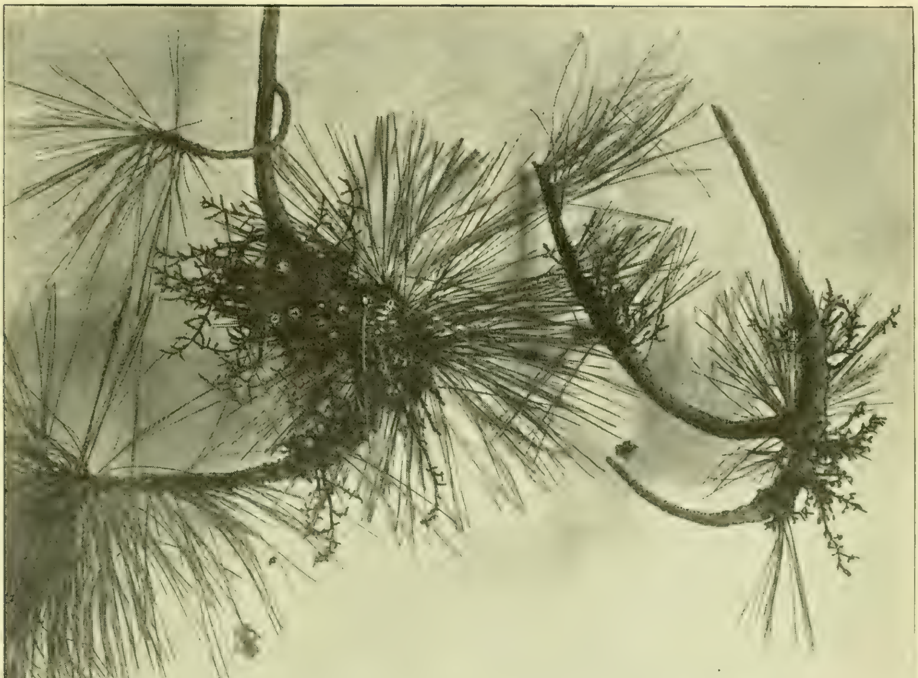

PLATE XVI.

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XIII. OBSERVATIONS ON CONSTANTINEA.

E. M. Freeman.

History and Literature.—The earliest mention of the red seaweed now classified under *Constantinea* is found in Gmelin's* *Historia Fucorum* published in 1768, in which he describes *Fucus rosa-marina* from the material collected by G. W. Steller during the years 1742–1745 at Kamtschatka. The description is as follows: "Peculiare sistet hæc planta fuci specimen, cujus exemplum aliud in omni reliqua fucorum historia non occurrit. Caulis teres est, carnosus, pennæ anserinæ crasitie, ramis sibi similibus, quibus, tanquam totidem pendiculis, adplicantur verticillatim folia petaloidea terna vel plura, rotunda, concava, circulo in centro notata, pulchre expansa, plerumque sissa, ramo per illa penetrante, exeunte, et pollicis dimidii intervallo nova fronde priori simili, prolifico, tertia nunnunquam pari ratione accedente. Petala convoluta pulchre repræsentant flores polypetalos, ut Rosam, anemonen, cet. Substantia tota gelatinoso-membranacea, aqua dissoluenda, pellucida. Color e rubro flavescens. Magnitudo semipedalis. Locus. Circa Lapatka inter spongias ad Kamtschatcam occurrit."

Such terms as "petala convoluta," "flores polypetalos," etc., show what a profound impression the superficial resemblance of the described plant to a rose had made upon the author.

In the years 1826–1829 the Russian vessel Seniavin, Fr. Lütke, Captain by the order of Czar Nicolaus I., sailed through Russian waters and collected a large amount of valuable algological material. The results were published in 1840 by Postels and Ruprecht in their *Illustrationes Algarum in itinere*, etc. The authors in their preface to this work state that the collections of H. Mertens and the plates of Alex. Postels form the basis of the entire work. The genus *Constantinea* is here described, founded upon Gmelin's *Fucus rosa-marina*, and three species are recognized, *Constantinea rosa-marina*, *C. sitchensis* and *C. reniformis*.

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* Gmelin, S. G. Hist. Fuc. 102. *pl. 5*, *f. 2*, *2a*. 1768.

According to the descriptions the first two species of *Constantinea* differ in the length of stipe between annuli, the mode of branching of the stipe and in the nature of the edge of the frond. The following are also noted: *Constantinea rosa-marina* is the smaller (one-half foot or less); branched even to the base; terminal frond two inches in diameter, laciniate (laciniæ 3–6), rarely remaining entire; 2–4 laminæ under the terminal one laciniate in a similar manner. *C. sitchensis* has solitary terminal fronds at the apices of the branches; the fronds are 4–6 inches in diameter, entire but laciniate when older; young fronds are often 8 lines in diameter.

In these supplementary descriptions all differences are compromised except the following: length of the "internode" of the stipe; the number of fronds on each branch; the method of branching of the stipe and the difference in size. The tetraspores of *C. sitchensis* alone are described. The "gongyli rotundi" as Kützing* has since pointed out are but ordinary cells of the intermediate layers of the frond. Postels and Ruprecht also mention *Constantinea reniformis*, a rare Mediterranean plant supposedly of this genus.

In 1843 Zanardini† described the *C. reniformis* of Postels and Ruprecht under the name of *Neurocaulon foliosum* from material collected on the shores of Dalmatia in the Adriatic. In the same year Kützing‡ called attention to the incorrect view of Postels and Ruprecht concerning the "gongyli rotundi" and to the great similarity in vegetative structure but great difference in outward appearance and tetraspore formation between *Constantinea* and *Euhymenia*. He describes the tetraspores and states that the cystocarps are unknown. His statements are evidently based solely on Postels, and Ruprecht's observations.

In *Species Algarum*, 1849,§ the two arctic species of Postels and Ruprecht are described under *Neurocaulon* as *N. rosa-marina* and *N. sitchensis*.

Two years later J. Agardh || accepts the Postels and Ruprecht generic name of *Constantinea* and adds to the previous description of the vegetative parts and tetraspores that of the cysto-

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* Kützing. Phyc. Gen. 400. 1843.

† Zanardini. Saggio class. 49. 1843.

‡ Kützing. l. c.

§ Kützing. Spec. Algar, 744. 1849.

|| Agardh, J. Spec. Gen. et Ord. Algar. **2**: 295. 1851.

carps. Since no new observations nor collections of the arctic species are cited, his generic description of the cystocarp is probably based upon *Constantinea reniformis*, the Mediterranean species. The cystocarps are described as "kalidia in media fronde numerosa, clausa, disruptione partis ambientis demum liberata, nucleolis pluribus composita; nucleoli intra periderma gelatinosum hyalinum gemmidia, nullo ordine disposita foventes." The zonate division of the tetraspores is noted. The collections of *C. reniformis* cited are: In the Adriatic sea on the shores of Dalmatia (Meneghini! and Zanardini!) and in the Mediterranean sea at Cette (Salzman!) and at Marseilles (Solier!). Nothing new is added concerning *C. sitchensis* and *C. rosa-marina*, but *C. reniformis* is fully discussed. The latter had been collected also by Mertens and described by him under the name of *Kalymenia reniformis*. In 1822 it was described by Agardh * under the name of *Halymenia reniformis*, and Postels and Ruprecht † describe it as a third species of *Constantinea—C. reniformis*. In 1822 J. Agardh ‡ stated that the tetraspores of *C. reniformis* had not been found.

Harvey's description of *Constantinea* in 1858 § is based upon the observations and literature cited above. The similarity in structure and the difference in external form and in position of tetraspores is noted. The branching of the stipe is described as at first irregular but later dichotomous; the dichotomy, however, is often lost in the abortion of one branch.

In 1862 in a notice of a collection of algæ made by Dr. David Lyall at Vancouver Island in the years 1859–1861, by W. H. Harvey ‖ specimens of *Constantinea sitchensis* with torn laminæ which were probably six to eight inches in diameter when perfect were reported "adrift on the beach at Victoria harbor." And Harvey observes that "perhaps this is only a luxuriant state of *Constantinea rosa-marina*."

In Kützing's work of 1867¶ the genus is again described under *Neurocaulon* and *N. foliosum* and *N. rosa-marina* are mentioned. The work of Postels and Ruprecht is not cited.

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* Agardh. Spec. Alg. 201. 1822.

† Postels and Ruprecht. Ill. Alg. 17. 1840.

‡ Agardh, J. l. c.

§ Harvey, W. H. Nereis Boreali-Americana 2: 173. 1853.

‖ Harvey, W. H. Journ. Proc. Linn. Soc. Bot. 6: 172. 1862.

¶ Kützing. Tab. Phyc. 17: 24. *pl. 83*. 1867.

Mention is again made of the genus by J. Agardh in 1876.[*] He had seen specimens of *C. rosa-marina* from the Museum of St. Petersburg and also a plant from Californian shores which he referred to *C. sitchensis;* but on account of inability to satisfy himself as to the structure of the fruiting bodies he based his descriptions upon those of Postels and Ruprecht.

In 1885 *Constantinea thiebauti* was described by Bornet[†] from a single specimen collected at Majunga on the north coast of Madagascar. Bornet very properly calls attention to the remarkable range which this genus, with the addition of his new species would enjoy: *C. rosa-marina* and *C. sitchensis* in arctic seas, *C. reniformis* in the deep waters of the Mediterranean and *C. thiebauti* in the tropical waters of the Indian ocean.

In 1891 there appeared in the Botanical Magazine of Tokyo "Remarks on some algæ from Hokkaido"[‡] in which *Constantinea sitchensis* Post. and Rupr. (?) is mentioned, but the position of the described plants in the genus *Constantinea* is admitted to be doubtful.

In "Die Natürlichen Pflanzenfamilien"[§] the genus undergoes rearrangement. *C. reniformis* is restored to the genus *Neurocaulon* of Zanardini, where probably should also be placed Bornet's *C. thiebauti*. The reproductive bodies, as well as the vegetative structure of *C. rosa-marina* and *N. foliosum*, had been studied personally by Schmitz.[‖] The classification of Schmitz and Hauptfleisch includes under *Constantinea* the species *C. sitchensis* and *C. rosa-marina* and under *Neurocaulon* the single species *N. foliosum*. I have no certain knowledge as to whether Schmitz had or had not in possession any material of *C. sitchensis*.

Collection.—In August, 1897, and again in the summer of 1898 collections of a species of *Constantinea*, reported as *C. sitchensis*, were made by Miss Josephine E. Tilden, and it is upon this material that the following observations are based:

On August 3, 1897, specimens of *C. sitchensis* were found growing upon holdfasts of *Nereocystis lütkeana* in 8 fathoms of water at Channel Rocks, near Seattle, Washington. During the summer of 1898 large collections were made at many of the stations where Dr. Lyall collected in 1859–1861. Collections were made at the following places: (1) Fairhaven, Washington. May 25. Washed up on the beach. (2) Near Minnesota reef, San Juan island, Washington. June 5. Attached to stones on a flat, sandy beach. This and the three following were found just below lowest tide. (3) Near Friday Harbor, San Juan island, Washington. June 5. Attached to rocks on rocky, steep beach. (4) Oak Bay (a suburb of Victoria), British Columbia. July 1. On a sandy beach. (5) Esquimalt, British Columbia. July 2. Attached to rocks. The first and last two collections contained abundant tetraspore material.

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[*] Agardh, J. Spec. Alg. 3: 225. 1876.

[†] Bornet. Alg. de Mad. Bull. Soc. Bot. de France 32: 18. *f. 1. 2.* 1885.

[‡] Okamura, R. Remarks on some algæ fron Hokkaido. Bot. Mag. Tokyo. 5: 333–336. 1891.

[§] Schmitz and Hauptfleisch. Nat. Pflanz. I. Teil. Abt. 2: 517, 519, 520, 525. 1897.

[‖] Schmitz. Sys. Übers. der bisher bekannten Gattungen der Florideen. Flora 72: 436. 1889.

Preservation.—The material collected in 1897 was killed and preserved in 80% alcohol. Owing to the small amount of this material and to the better condition of that collected in 1898, all of the following drawings except Fig. 1 have been made from the 1898 material. The larger part of it was killed and preserved in a 2 per cent. formalin solution in sea water. In this the color was very well preserved. The firmness of the tissues, however, suffered considerably more in the formalin-solution material than did that of the alcohol material of 1897. The formalin material was still sufficiently firm to admit of very satisfactory manipulation. Still other plants were preserved in camphor water, and some in 1 per cent. chromic acid solution. The camphor material lost its color almost as completely as the alcoholic. It preserved, however, a great firmness, which rendered the tissues excellent for section cutting, and especially for hand sections. The gelatinous cell walls, however, were so cleared that they were not as easily defined as in the formalin material. The chromic acid collections were in a poor state of preservation; the tissues were very soft, the cell walls almost invisible and the contents usually, at least partially, disorganized.

Methods.—Various methods were employed in cutting the tissues. A part of the material was transferred directly from water to 20 per cent. glycerine, thence to a gum arabic solution upon an Osterhout freezing chamber.* Material was sometimes placed directly from the sea water on the freezing chamber with results almost, if not equal, to those obtained when it was passed first into 20 per cent. glycerine. When the sections were removed from the knife they were placed in 20 per cent. glycerine, and from this into 50 per cent. and then into absolute glycerine; or from 20 per cent. glycerine to water and then through the alcohols to an alcohol stain or directly into a water stain. The freezing device mentioned above proved very satisfactory in many respects. The tissues can be frozen in a minute's time, are held firmly in place, and the gum arabic, when of the proper consistency, is an excellent imbedding medium. The difficulty experienced with this method of cutting such delicate tissues as are found in many of the seaweeds lies in the handling of sections after they are cut. Especially is this true when it is desirable to stain the sections and when they must be transferred through several per cents. of alcohol and glycerine. With such tissues as are found in the frond of *Constantinea*, where they part with great ease, the difficulty is augmented, and it was found almost impossible to preserve thin sections whole. An attempt was made to obviate this difficulty by mounting the sections directly from the microtome knife into glycerine jelly at a temperature sufficient to keep the jelly semi-fluid. This was in part an improvement, but necessitated the mounting of many worthless sections. When sections unstained were mounted in glycerine or glycerine jelly, the great transparency of the swollen cell walls added a new difficulty.

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*Osterhout, W. J. V. Bot. Gaz. 21: 195. 1896.

Material was also passed into paraffin and stained on the slide and mounted in Canada balsam by the usual methods. Extreme care was found necessary, on account of the delicacy of the tissues, to make the stages from one fluid to another by very gradual changes. I was unable to prevent a partial shrinkage of the cell contents. Sections by this method were otherwise quite satisfactory, having the advantage of use in serial work. Staining is necessary in this method since the sections become almost invisible in Canada balsam.

Sections cut freehand with a razor or in a hand microtome with the material imbedded in pith have furnished most of the material from which the accompanying plates are drawn. Sufficiently thin sections were obtainable in this way with the great advantage of certainty as to the normal condition of the tissues and of speed in preparation. A large number of such sections can be cut and preserved in 2 per cent. formalin for a long time and are ready for use at any moment.

A number of staining fluids were used, section staining, either on or off the slide proving more satisfactory than staining in toto. Aniline stains were used almost exclusively. The following were employed with at least some degree of success:

Aniline blue: Stains the gelatinous wall of the cells pale blue, the chromatophores of the cortical cells deep blue and the contents of the tetraspores and of the paraphyses light blue. The central part of the pyrenoids of the endophytic alga which is usually present in these collections takes on a light blue. The best results were obtained with a 40 or 60 per cent. alcoholic solution, acting from 24 to 36 hours. For sections on the slide 5 to 10 minutes in a strong 60 per cent. alcoholic solution was usually sufficient. My best staining results were obtained from aniline blue.

Methylen blue: Stains the cell walls, especially the outer portions, which become quite clearly defined. Sections were stained in a strong 95 per cent. alcoholic solution from 5 to 10 minutes.

Fuchsin: Best results were obtained from sections left in a 10 per cent. alcoholic solution 36 hours. The gelatinous walls were stained light red while the protoplasm of the paraphyses and chromatophores of the cortical cells took up a deep carmine red.

Delafield's hæmatoxylin: Same strength and time as fuchsin. The granular contents of the cells are stained a reddish purple.

Several other stains were used, but without success. In a weak solution of iodine in potassium iodide the granules of the cells of the middle and intermediate layers assume at first a yellowish-brown tinge which finally deepens to an amethyst purple. Stained in a strong solution for a few moments these areas take on a dense violet color.

Gross Anatomy.—In general form *Constantinea* presents several interesting peculiarities. (Figs. 1–6.) The plant is differentiated into a cylindrical stipe and peltate frond at its summit. It is of a purple-reddish color, stands upright in the water below lowest low tide mark, and the texture is quite firm and brittle. It is somewhat gregarious in habit. The stipe is "terete, branched, ringed and the apex of each branch expanded into an orbicular peltate lamina; stipe 1–4 mm. in diameter, 2–8 cm. in length; lamina 2 cm.–3 dcm. in diameter." (Tilden, Am. Alg. no. 203. 1897.) The laminæ have numerous minute dark brownish spots on their upper surfaces. The older fronds are irregularly perforated with circular holes and are more or less torn at the edges (Fig. 3). When young the fronds are entire (Fig. 2). As the plant continues its growth the stem pushes up through the center of the frond, forming a new growing point which elongates into an internode and soon forms another frond at its summit. The old frond then falls off, leaving an annulate marking on the stipe (Figs. 5, 6). There is often, especially in the youngest portions of the oldest plants, a formation of two growing points at the center of each lamina giving rise to a dichotomy of the stipe (Fig. 5). Irregularity in the development of these growing points gives rise to an irregular system of branching (Fig. 5). Growing points are not confined to the bases of laminæ but may be found occasionally arising from other portions of the stipe. There are often a group of small branches formed upon the holdfast (Fig. 1). The latter is a disc-like body arising as an expanded portion of the stipe at its base and usually concave below (Fig. 22).

Upon the lower surface of the fronds especially the larger ones, can be seen distinct radial striations caused by small ridges running from the region near the stipe toward the edge of the frond (Fig. 4). These mark the course of bundles of elongated narrow filaments (see below). The nemathecia which bear the tetraspores are found only on the lower surface of the frond. They occur more abundantly on the larger fronds and are often so numerous as to almost completely cover the under surface. They form small wart-like bodies of whitish color and gelatinous consistency.

Minute Anatomy.—As is well known the thallus of the red seaweed is a group of dichotomously branching filaments whose fused branches form tissue-like areas. In *Constantinea* this method of branching can readily be seen in the frond but particularly so in the cortical area of the stipe (Fig. 18).

Frond.—A cross section of the frond shows three areas of cells: (*a*) a central layer of loosely woven filaments; (*b*) an intermediate layer of large approximately spherical cells stuffed with starch granules (Fig. 7); (*c*) a cortical layer of pseudo-parenchymatous cells.

a. There are in the central area filaments of large cells, usually slightly elongated, often stretching across the frond and perpendicular to the frond surface (Fig. 11). These cells approach the large cells of the intermediate layer in form and size, transitional stages between them being abundant (Figs. 8, 9, 10). Their average size is 55 mic. x 12 mic., but they may attain 75 x 16 mic. A cross section of the lower part of the frond, tangential to its orbicular outline, shows in the central area at more or less regular intervals corresponding to the external striation on the lower surface of the frond, a number of bundles of greatly elongated cells, woven into strengthening bundles (Figs. 7, 8, 9). In the lower region the general course of these bundles is radial in the frond. Divergence from this course is found in the upper part so that a tangential cross section of the frond shows some of these bundles in longitudinal or oblique section (Fig. 9). These filaments are articulated; the cells often attain a length of 325 mic. They average about 8 mic. in breadth. Thin sections of the frond often contain clean-cut circular spaces where the bundles of elongated cells have been pulled out, showing the compactness of the bundles and indicating for it a strengthening function. The bundles vary in size; the striations on the lower surface of the frond mark only the largest bundles.

b. The typical cells of the intermediate area are spherical and average 46 mic. in diameter. They are packed with Floridian starch granules which turn brownish with a weak KI solution of iodine and finally purple or violet in a strong solution. Those cells toward the surface of the frond contain ordinarily a few chromatophores, usually in the end near the surface. The cells of the intermediate layer shade off towards the surface into the cortical cells.

c. The cortical cells are characterized by a compact pseudoparenchymatous grouping in which the long diameters of the but slightly elongated cells are perpendicular to the frond surface. Many of the cells are approximately cylindrical or prismatic. The external layer is of a sufficient regularity in structure and form to recall forcibly an epidermal layer. In these the outer wall is rounded. The cells of the cortical layer contain but a small amount of starch, and this is found in the cells adjoining the intermediate layer. Chromatophores are, however, abundant and more numerous toward the frond surface. Almost all of them are to be found in the first three or four rows of cells from the surface (Fig. 10), but some are found in still deeper layers. They occupy, in the great majority of cases, a position in the peripheral end of the cell. Under the microscope they appear finely rose-colored pink with perhaps a purple tinge. They are irregular in outline, apparently in most cases assuming such a shape as will allow them to occupy the peripheral end of the cell to best advantage. The epidermal cells average about 13 x 5 mic. and the chromatophores about 10 x 2 mic.

Stipe.—(Figs. 14–21). A cross section of the stipe shows a similarity in structure to that of the frond. The same areas are present with modifications, however (Fig. 14). The cortical area is composed of cells more elongated than those in the frond and is a larger number of cells deep. Internally these pass into the large cells of the intermediate area (Fig. 19). Here there is a noticeable difference from the condition in the frond. A large number of the elongated central cells find their way into this area and a cross section of the stipe shows them in cross, oblique and even longitudinal section between the large starch-containing cells of the intermediate area which stand out very clearly in large radial filaments (Fig. 21). The central area in the stipe is a very compact area and is made up of a large number of thin filaments interwoven in a very complicated manner (Figs. 20, 21). These cells correspond to those of the elongated filament bundles in the frond. There are in the stipe, moreover, a small number of larger cells also elongated and corresponding to the cells of similar shape and position in the frond. In cross section the cut-off ends predominate (Fig. 20), while in longitudinal section the cut-off ends are few; the longitudinal view of the filaments is the predominant one and the intricate weaving (Fig. 21) is very plainly seen. A longitudinal section through the annulate portion shows the absence of the cortical and intermediate layers in the region of the annulus indicating the continuity of these areas in the frond and stipe (Fig. 15).

A longitudinal section through the growing point shows but two areas in the growing region. There is no distinct intermediate area although a number of large cells may be present (Fig. 16). The two areas are the cortical in which the filaments are all parallel, perpendicular to the stipe surface and pseudo-parenchymatous in character, and the central, which is as before a mass of densely woven elongated filaments. The end of the intermediate area of the frond can readily be seen in such a section (Fig. 16).

Holdfast.—The holdfast, *i. e.*, the expanded portion of the stipe at its base, presents a similar anatomical structure to that of the stipe with the exception of one modification. The lower cortical and intermediate areas which are in contact with the surface to which the plant is moored are changed into a yellowish brown disorganized mass which probably serves as a cementing substance in attaching the plant to the rocks. Indications of the former cell structure can be seen in occasional cavities and in the arrangement of these cavities. The area adjoining the cement layer is composed largely of elongated filaments (Fig. 24).

Protoplasmic Connections.—In freshly cut material the protoplasmic connections between cells, is very plainly to be seen in many of the starch cells of the intermediate area. They are also easily seen in the larger cells of the central area, as well as in the small cells of the same area. The cortical area of the stipe furnishes particularly good views of this continuity (Figs. 13, 18).

Reproductive Tract (Figs. 11, 12).—I have been unable to find, in the material at hand, and it is considerable in amount, any trace of cystocarp development. The following description of the occurrence and structure of the cystocarp of the genus is translated from Schmitz and Hauptfleisch,* the former of whom has made a personal study of the cystocarp of *C. rosa-marina* (Schmitz, l. c.): The carpogonial branches and auxiliary cell branches are distributed in the fertile portions of the frond in large numbers in the loosened inner portion of the inner cortex of the upper side of the leaf, together with numerous vermiform sterile cellular threads. Cystocarps distributed in large numbers on the fertile fronds, comprising a broad zone along the edge of the frond on its upper surface, imbedded in the much loosened inner cortex of the upper surface of the frond, swelling out into an arch the superposed outer cortex which is punctured by pores. The nucleus of the form of a mulberry and pierced by single strands of sterile tissue. Gonimolobes separated only at first, later confluent.

Kützing † states that the "gongyli rotundi" described by Postels and Ruprecht as two kinds of fruiting bodies in *Constantinea rosa-marina* are ordinary cells of the cubcortical layer.

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* Schmitz and Hauptfleisch. In Engl. and Prantl. Nat. Pflanz. I. Teil. Abth. 2. 520, 521. 1897.

† Phyc. Gen. 400. 1843.

Tetraspores are known only in *C. sitchensis.* They are oblong and zonate, lodged in nemathecia. The nemathecia are found exclusively on the lower surface of the frond more abundant near the outer half. They are in the form of delicate, slightly-raised "wart-like," often confluent bodies of a whitish color. They average 3.5–4 mm. in diameter and often become so numerous that they completely cover a very large part of the lower surface of the frond. The nemathecia are covered by the gelatinous layer on the surface of the paraphyses. The paraphyses are elongated, narrow, peripheral cells (Figs. 11, 12). The tetraspores arise as club-shaped elongations of peripheral cells between the paraphyses and are divided zonately into four chambers. The tetraspores are numerous in each nemathecium. Their average size is 108 x 22 mic.

Endophyte.—In a large majority of sections and upon all material examined, are present peculiar green approximately spherical bodies imbedded in the cortical tissue of the frond. They are endophytic algæ and probably the *Chlorochytrium inclusum* of Kjellman. In general they are pear-shaped with their small end toward the surface and the cell wall at that end thickened. They are greenish in color and contain a number of conspicuous pyrenoids, the central areas of which stain very readily, having a particular affinity for aniline blue. The protoplasm is denser toward the small end where the cell wall is also thick. It is with this end that the endophyte breaks through the cortical tissues of the nurse plant. I have as yet been unable to detect any zoöspore formation. This interesting little endophyte will receive a more complete discussion in a subsequent paper.

Conclusions.—The material upon which these observations are based was distributed by Miss Tilden as *Constantinea sitchensis* Post. and Ruprecht. A careful comparison of it with the plates and descriptions of Postels and Ruprecht shows however that the plant under observation might as well perhaps be placed under *Constantinea rosa-marina.* The material agrees in almost every particular with *C. rosa-marina* having, however, single terminal fronds and an occasional evident dichotomy of branching. The differences enumerated above in the descriptions of the two species can hardly be considered of specific importance. The length of the internodes may vary considerably. The greater part of the material under observation contained long internodes. This material was collected in late summer. The number of fronds on a branch is also given specific value by Postels and Ruprecht. It is probably of important significance that *no* tetraspores were found by these authors upon *C. rosa-marina* but that large numbers were found upon *C. sitchensis.* Figure 6 represents a young frond having no tetraspores but with a succession of fronds similar to those of *C. rosa-marina*, while almost all of the remaining material had solitary terminal fronds crowded with tetraspores. The material collected in May, 1897, contains tetraspores.

The dichotomy of the branching of *C. sitchensis* is a comparatively late development in the growth of the stipe and is not seen in the older parts. *C. sitchensis* is further described as larger in all parts than *C. rosa-marina*, though actual measurements given do not accord with this. *These facts suggest the probability that the C. sitchensis of Postels and Ruprecht is the late summer stage of C. rosa-marina.* This supposition explains satisfactorily the absence of tetraspores in the one and of dichotomy of the stipe in the other, the comparative lengths of " internodes " and the difference in sizes of the two plants.

The observations and impressions of subsequent writers add additional weight to this view. In recounting the founding of the genus by Postels and Ruprecht upon the *Fucus rosa-marina* of Gmelin, Agardh (l. c. 1851) observes of *C. sitchensis* " novo consimili adjecta specie " (p. 294) and of *C. rosa-marina* " præcedente (sitchensis) videtur proxima, cum nulla alia confundenda " (p. 296).

Of the material collected by David Lyall at Vancouver island " adrift on the beach at Victoria harbor " and reported as *C. sitchensis*, although corresponding in size to *C. sitchensis* Harvey (l. c. 1862) remarks " perhaps this is only a luxuriant state of *C. rosa-marina*."

From these facts it would seem, therefore, highly probable that *C. sitchensis* and *C. rosa-marina* are but different forms of the same plant, and since the work of Schmitz has removed *C. reniformis* to the genus *Neurocaulon* where also it is probable that *C. thiebauti* should be classified, that *Constantinea* is a monotypic genus, with *Constantinea rosa-marina* as the only species.

Description of Plates.

Fig. 1. Young plant with group of young branches on the holdfast. x ½.

Fig. 2. Portion of the plant showing the entire edge and form of young fronds (from dried material). x ½.

Fig. 3. An old frond showing lacerated border and perforations (from dried material). x ¼.

Fig. 4. A frond showing striations on the lower surface (dried specimen). x ½.

Fig. 5. Plant with fronds almost entirely cut away showing the growing points, the annulations of the stipe and the dichotomous branching. *a.* annulations. *g. p.* growing point. *f.* frond cut off. x ½.

Fig. 6. Small branch showing a rapid succession of laminæ. x ½.

Fig. 7. Diagram of a tangential cross section of the frond. *c.* cortical area. *int.* intermediate. *e.* bundles of enlarged filaments. *l.* loosely woven cells of central area.

Fig. 8. Cross section of a frond showing bundle of elongated cells in central area in transverse section. Letters as above. Drawn with camera lucida. x 250.

Fig. 9. Cross section of a frond showing a longitudinal section of a part of a bundle of elongated central cells. Drawn with camera lucida. x 250.

Fig. 10. Cross section of a frond stained for a minute in a strong solution of I in KI. *ch.* chromatophores. *st.* starch grains. Drawn with camera lucida. x 345.

Fig. 11. Cross section of a frond through a nemathecium. *cent.* central layer. *p.* paraphyses. *t.* tetraspores. Cells are drawn only in outline. Contents have been omitted. Camera lucida. x 83.

Fig. 12. Cross section of a frond through a nemathecium showing tetraspores. Drawn from a glycerine mount in which the gelatinous walls became almost entirely obliterated. The walls are, therefore, omitted except around the tetraspores. x 250.

Fig. 13. Cells from central area showing protoplasmic connections. Camera lucida. x 250.

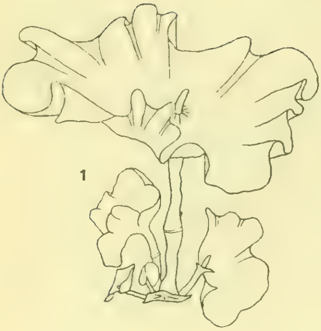
Fig. 14. Diagram of cross section of stipe in internode. Letters as in frond.

Fig. 15. Diagram of longitudinal section of a stipe through a node.

Fig. 16. Diagram of a longitudinal section of the stipe through a growing point.

Fig. 17. Peripheral cells from cross section of stipe showing the striations in the outer gelatinous covering. x 345.

Fig. 18. Filament from a cross section of the stipe in the cortical



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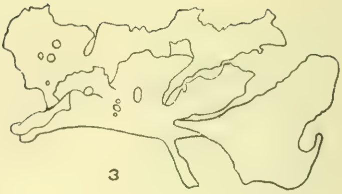

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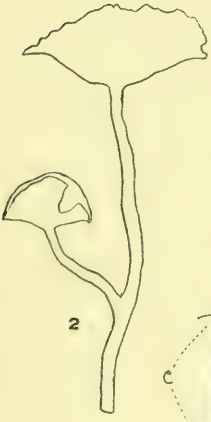

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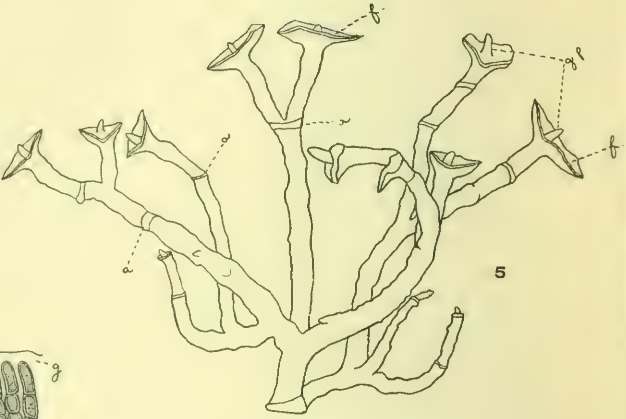

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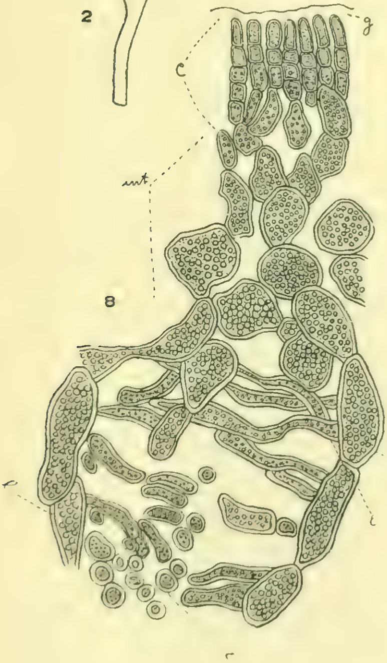

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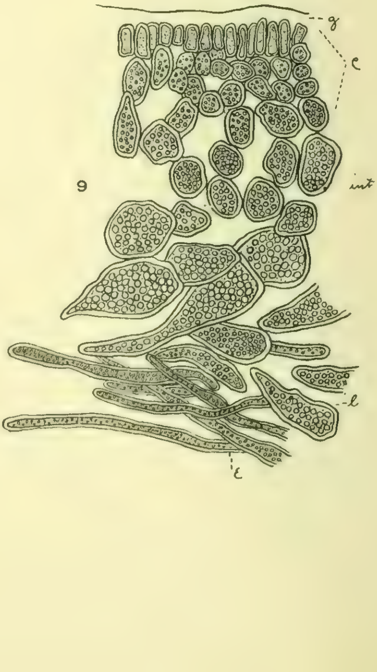

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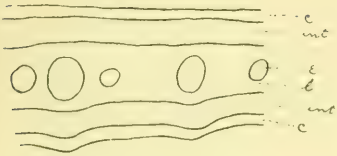

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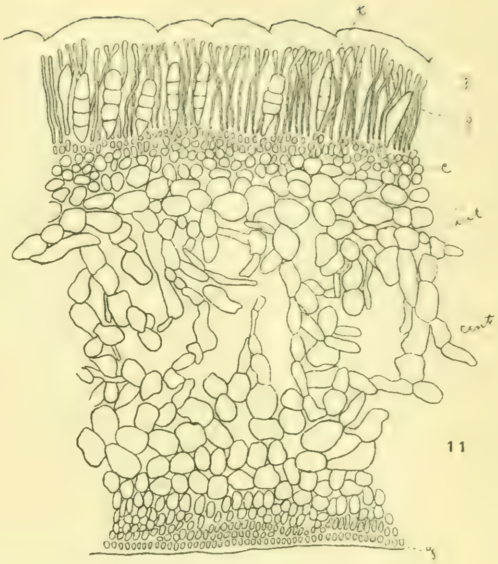

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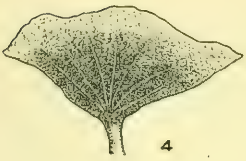

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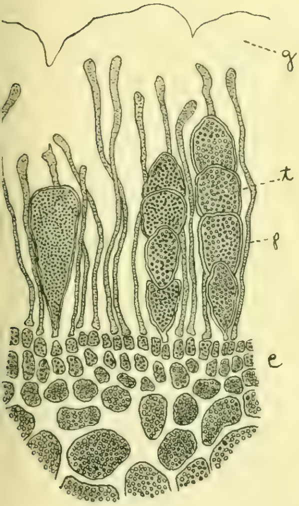

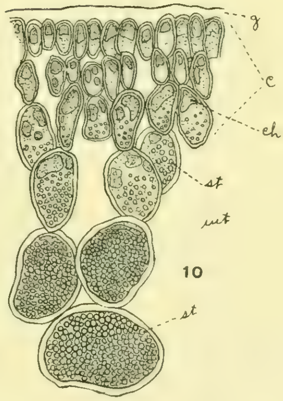

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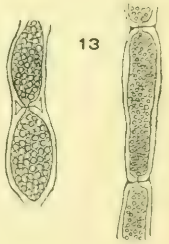

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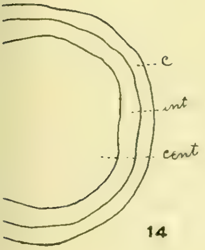

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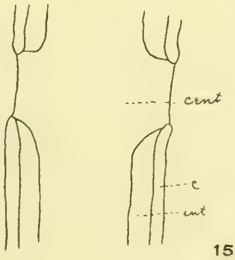

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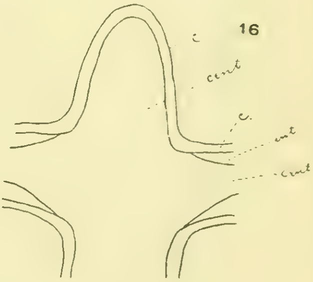

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XVII.

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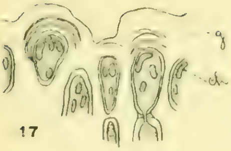
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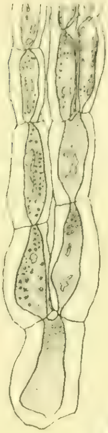
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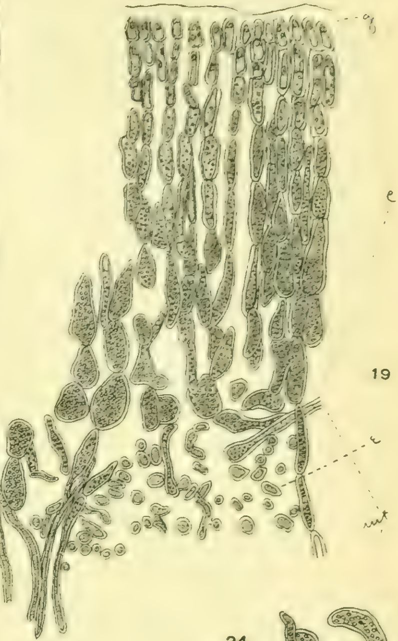
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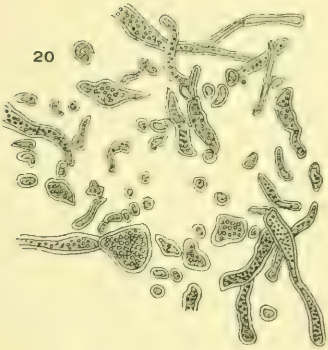
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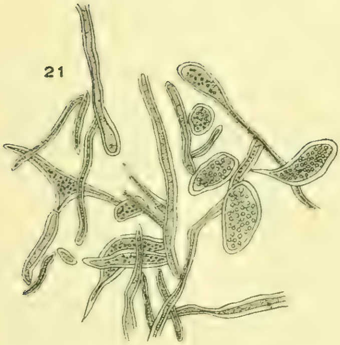
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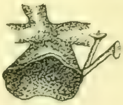
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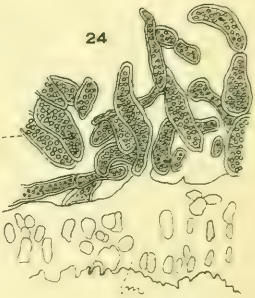
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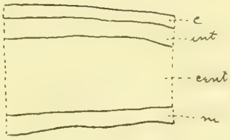
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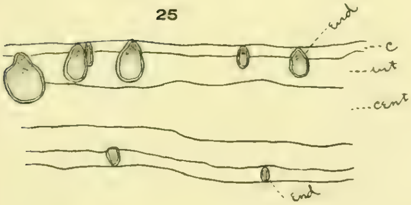
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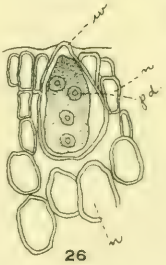
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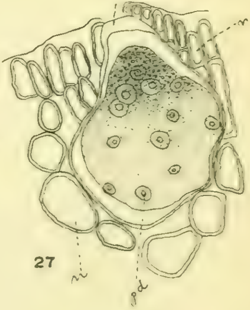
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PLATE XVIII

HELIOTYPE PRINTING CO. BOSTON

area showing the dichotomy of the branching. Camera lucida for an outline. x 250.

Fig. 19. Cross section of stipe including the cortical and the beginning of intermediate layer. The cut off ends of elongated central filaments are seen in the intermediate area. Camera lucida. x 130.

Fig. 20. Cross section of stipe in the central area; shows the predominance of elongated filaments. x 250. Outlined with camera lucida.

Fig. 21. Longitudinal section of a stipe at the inner edge of the cortex; shows the complication of the elongated filaments. Outlined with camera lucida. x 250.

Fig. 22. External view of holdfast seen from below. x ½.

Fig. 23. Diagram of cross section of a holdfast. *m.* layer of disorganized mass on lower surface by which the holdfast adheres.

Fig. 24. Lower portion of the cross section of the holdfast showing the attaching layer *m.* Camera lucida. x 250.

Fig. 25. Diagram of a cross section of a frond showing the distribution of an endophytic alga (probably *Chlorochytrium*). Larger number on the upper surface. *end.* endophyte.

Figs. 26 and 27. Cross section of a frond; detail drawing of endophyte. *w.* endophyte wall. *pd.* pyrenoid. *n.* cell of nurse plant in outline. Camera lucida. x 250.

BIBLIOGRAPHY.

1. Gmelin, S. G. Historia Fucorum. 1768.

2. Postels, A., and Ruprecht, F. Illustrationes Algarum in itinere circa orbem jussu Imperatoris Nicolai. I. 18, *pl. 49, f. 88.* 1840.

3. Zanardini, G. Saggio di classificazione naturale delle Ficee con nuovi Studi sopra l'Androsace degli Antichi. 49. 1843.

4. Kützing, F. T. Phycologia Generalis. 400. 1843.

5. Kützing, F. T. Species Algarum. 744. 1849.

6. Agardh, J. Species, Genera et Ordines Algarum. **2**: 295. 1851.

7. Harvey, W. H. Nereis Boreali-Americana **1**: 21; **2**: 160, 173. 1853.

8. Harvey, W. H. Notice of a Collection of Algæ made on the Northwest Coast of North America, chiefly at Vancouver's Island, by David Lyall, Esq., M.D., R.N., in the years 1859–61. Journ. Linn. Soc. Bot. **6**: 172. 1862.

9. Kützing, F. T. Tabulæ Phycologicæ **17**: 24. *pl. 83.* 1867.

10. Zanardini, G. Iconographia Phycologica Adriatica **2**: *pl. 78.* 1860–76.

11. Agardh, J. Species, Genera et Ordines Algarum. **3**: 225. 1876.

12. Bornet, E. Algues de Madagascar recolteés par M. Ch. Thiebaut. Bull. Soc. Bot. de France. **32**: 18. *f. 1, 2.* 1885.

13. Hauck, F. Die Meeresalgen, in Rabenhorst's Krypt. Fl. **2**: 146. 1885.

14. Schmitz, F. Systematische Übersicht der bisher bekannten Gattungen der Florideen. Flora **72**: 435–456. 1889.

15. Okamura, R. Remarks on some algæ from Hokkaido. Bot. Mag. Tokyo **5**: 333–336. 1891.

16. Schmitz, F., and Hauptfleisch, P. Die natürlichen Pflanzenfamilien. I. Teil. Abt. 2. 517, 519, 520, 525. 1897.

XIV. EXTENSION OF PLANT RANGES IN THE UPPER MINNESOTA VALLEY.

L. R. MOYER.

The following notes refer to plants that have been collected in the upper Minnesota valley since the publication of Professor MacMillan's *Metaspermæ of the Minnesota Valley*. Duplicates have been deposited in the Herbarium at the State University.

Thlaspi arvense L.

This old world crucifer has become well established in the railroad yards at Montevideo and is spreading rapidly.

Conringia orientalis (L.) DUMORT.

This plant, first collected in wheat fields in Chippewa County in 1894, is spreading very rapidly and seems likely to become one of the worst "mustards" with which the farmer has to contend.

Sisymbrium altissimum L.

This plant, too, is spreading very rapidly along the railroad tracks at Montevideo, and seems likely to become a very troublesome weed.

Peucedanum nudicaule (PURSH) NUTT.

This plant is found to be quite plentiful in the upper Minnesota valley on thin gravelly land near ledges of igneous rock. It is one of the earliest spring flowers.

Potentilla hippiana LEHM.

This western *Potentilla* is occasionally found on ledges of gneiss rock near Montevideo.

Helianthus annuus L.

Among the recent arrivals at Montevideo, an immigrant from the West, is the annual sunflower. It is traveling along the railroads.

Grindelia squarrosa (PURSH) DUNAL.

This is another western plant that seems to be traveling east. It has but recently become well established in the railroad yards at Montevideo.

Lactuca scariola L.

Another Old World weed that has but recently arrived at Montevideo is this species. It is spreading with great rapidity.

Senecio vulgaris L.

Recently arrived at Montevideo, this plant is becoming common as a weed in gardens and waste grounds.

Poa pseudopratensis SCRIB. & RYD.

A *Poa* collected at Clara City, in Chippewa County, has been identified by Professor Lamson-Scribner as this species.

Fraxinus lanceolata BORCK.

A study of this species based on a large collection of material from the prairie portion of the State, some of which was sent east for comparison, makes it probable that all of our ash trees are referable to this species. *F. Americana* appears to be absent from western Minnesota.

Cactus viviparus NUTT.

This cactus is found quite abundantly on granite ledges in the ancient valley of the "Warren," about two miles southeast of Ortonville. Its bright red flowers are strikingly beautiful.

Astragalus flexuosus (HOOK.) DOUG.

This species is quite plentiful near the railroad yards at Ortonville.

XV. LIST OF HEPATICÆ COLLECTED ALONG THE INTERNATIONAL BOUNDARY BY J. M. HOLZINGER, 1897.

ALEXANDER W. EVANS.

1. **Aplozia autumnalis** (DC.) HEEG. F, N.
2. **Bazzania trilobata** (L.) S. F. GRAY. F, R, U.
3. **Blepharostoma trichophyllum** (L.) DUMORT. R.
4. **Cephalozia catenulata** (HÜBEN.) SPRUCE. F.
5. **C. media** LINDB. P.
6. **Frullania Eboracensis** GOTTSCHE. F.
7. **Jungermannia barbata** SCHREB. F, G, P.
8. **J. quinquedentata** WEB. P, R.
9. **J. ventricosa** DICKS. S.
10. **Lejeunea serpyllifolia** (DICKS.) LIB. U.
11. **Lepidozia reptans** (L.) DUMORT. P, R, S, U.
12. **Plagiochila asplenioides** (L.) DUMORT. N, P, U.
13. **Porella platyphylla** (L.) LINDB. F, U.
14. **Ptilidium ciliare** (L.) NEES. C, F, S, U.
15. **Radula complanata** (L.) DUMORT. C, F, U.
16. **Scapania glaucocephala** (TAYL.) AUST. F.

C = Camp IV., on the Prairie Portage, shore of Basswood Lake, near the rapids from Sucker Lake.

F = Fall Lake, near the foot of Kawasatchong Falls, seven miles north of Ely.

G = between Gunflint Lake and Grand Portage.

N = stream flowing from North Lake into Little Gunflint Lake.

P = Grand Portage Island.

R = Pipestone Rapids, on Basswood Lake.

S = Safety Island.

U = United States Peninsula.

XVI. OBSERVATIONS ON CHLOROCHYTRIUM.

E. M. Freeman.

In 1850 Mettenius found numerous green cells in the thallus of *Polyides lumbricalis* which resembled closely what are now classified as the Endosphæreæ of the Protococcaceæ. He interpreted them as spore-mother cells of the red seaweed upon which they were found. Thuret fourteen years later observed these same structures and interpreted them as parasitic zoöspores which on germination produce the bushy thallus of *Cladophora lanosa*. Cohn in 1865 was able to confirm the observations of Mettenius and of Thuret, except as to the germination of the endophyte into *Cladophora lanosa*.

The condition of endophytism was considered at that time as indicative of parasitism. Hence new interest was aroused in the investigation of these lower forms when Rees and Schwendener at about the same time (1871) advanced independently the theory that the *Collema* type of lichen is to be derived from a discomycetous fungus, the mycelium of which has penetrated the mucilage of a *Nostoc* completely surrounding the latter. Reinke's observations on *Nostoc* in the stems of *Gunnera scabra* and the work of Milde and Janczewski on *Nostocs* in liverworts demonstrated the occurrence of *Protococcus*-like algal forms in the plant tissues of higher plants. Cohn in 1872 suggested that the presence of the Nostoc filaments in *Gunnera* and *Anthoceros* is perhaps to be explained as an accidental entry of the movable *Nostoc* filaments into the tissues of the nurse plant, their continued growth in this new sheltered position and their subsequent imprisonment by the growth of the surrounding tissues of the nurse plant. In contrast to this form of endophytism Cohn describes the new genus *Chlorochytrium*, which he considers to be a true parasite in certain species of *Lemna*. The zoöspores, very numerous on the surface of the host, send out a germination tube between two epidermal cells. The membrane of this tube becomes thickened by subsequent layers, the tube swells with the absorption of the chlorophyll and protoplasm and the intercellular endophyte results, with a cellulose button protruding from the point where the germinating tube entered. The endophyte then becomes pyriform and almost opaque on account of the density of the chlorophyll. By free cell formation large cells are formed in the endophyte and these finally break into a large number of zoöspores which are expelled through the cellulose protuberance from the nurse-plant epidermis. The endophyte is, therefore, an independent organism closely related to *Hydrocytium* (*Characium* A. Br.) on the one hand and to *Synchytrium* on the other. With the Eu-Synchytrium group its cell form and the formation of zoöspores by a preliminary division into segments, corresponding to the zoösporangia of *Synchytrium*, agree, but it differs in the presence of chlorophyll and of a germination tube and in its intercellular position. Upon these observations Cohn founded the genus *Chlorochytrium* and described it as follows:

Planta endophytica viridis unicellaris, globosa ovoidea vel irregulariter curvata bi, tri, multiloba dense conferta plasmate viridi, primum in segmenta majora diviso dein secedente in zoosporas immersas pyriformes virides processibus tubulosis extus emissas.

Chlorochytrium lemnæ upon which the genus is based is then described.

Cohn pronounces *Chlorochytrium* a true parasite. That no deleterious effects upon the host are visible is paralleled in *Peronospora* and *Synchytrium*. In its intercellular position it resembles the Uredineæ.

Two years after Cohn's observations were published Kny described a new species of *Chlorochytrium* endophytic upon *Ceratophyllum demersum*. It differs from *Chlorochytrium lemnæ* in size and in the absence of a cellulose button.

In 1877 Wright established a third species of *Chlorochytrium*, *C. cohnii* Wright.

"The zoöspores impinging on the fronds of several species of marine algæ quickly assuming a figure-of-eight form, the lower sphere growing into the frond and rapidly assuming comparatively large dimensions, the upper sphere remaining as a tube-like neck portion to the larger mass. On the cell arriving at an adult stage, the whole of the green protoplasmic contents divides into a number of from 10–30 nearly circular zoöspores, which escape through the neck-shaped portion.

"Living in the thallus of various species of *Schizonema*, *Polysiphonia*, etc.; also on the Infusoria found at Howth."

Wright states further that there are two kinds of zoöspores, large and small, the latter being the more numerous.

Szymanski in 1878 described *C. knyanum* apparently identical with the plant mentioned by Kny four years before as inhabiting the tissues of *Ceratophyllum demersum*. This species was found on *Lemna minor* and possessed a cellulose button which did not protrude farther than twice the thickness of its outer wall above the epidermis of its nurse plant.

Klebs published the results of his investigations on *C. lemnæ* in 1881. *Chlorochytrium* in the younger vegetative stages contains a light green chlorophyll-bearing protoplasm with isolated starch grains surrounded by a cell sap vacuole (see below, pyrenoids). In the later stages the grains increase in number, the mesh-work of green bands becomes smaller, the chlorophyll darker until almost opaque and the protoplasm finally becomes coarsely granular. After a resting period of a week or more the zoöspores are formed by successive bipartitions of the cell contents, at first by perpendicular, later by radially disposed walls.

The number of divisions is not known. Liberation of the zoöspores is accomplished by absorption of water resulting in the splitting of the *Chlorochytrium* wall and of the superposed *Lemna* tissues.

The conjugation of the biciliate zoögametes into larger quadriciliate zoözygotes was observed, a fact which may throw light on the macro- and microzoöspores of Wright's species. Klebs observes that Cohn's account of the liberation of the zoöspores is without observational foundation and doubts its accuracy. He also calls in question the appropriateness of placing Wright's species in the genus *Chlorochytrium* and further suggests the probability that *C. knyanum* is but the asexual form of *C. lemnæ* since no copulation had been observed between the zoöspores. *C. pallidum* Klebs and many similar forms are probably mere "place varieties" of *C. knyanum*.

Klebs points out with much truth that no proof has been given of the much averred parasitism of *Chlorochytrium* by Cohn and other previous investigators. On the other hand *Chlorochytrium* has well developed chlorophyll and lives near the surface where abundant light is available. The requisite inorganic matter may gain access to the cells by the constant or at least periodical submersion in water.

Chlorochytrium lemnæ penetrates dead as well as living leaves and culture methods demonstrate an entire lack of dependence of the endophyte upon a host plant. In many endophytes zoöspores can be developed on culture slides for months. No proof has as yet been adduced for any injury of the host beyond the results of the mechanical pressure exerted. The explanation then of endophytism is to be found not in parasitism but in the mechanical protection of position, which the intercellular spaces of the host offered; hence the appropriateness of the term "Raum Parasiten." It is, of course, possible for parasitism to develop from such a condition and this development seems to be in evident progress in such a nearly related form as *Phyllobium dimorphum* and also perhaps in *Nostoc lichenoides*. In the systematic relations of *Chlorochytrium* and the nearly related genera, Klebs briefly points out the intermediate position of *Chlorochytrium* and *Endosphæra*, between the Protococcaceæ and the Chytrideæ, the isolated position of *Scotinosphæra* and the probable affinities of *Phyllobium* on the one hand with *Chlorochytrium* and on the other with *Botrydium*.

Schaärschmidt, 1881, found zoöspores of *Chlorochytrium* in a Desmid culture in which the zoöspores subsequently developed, confirming Kleb's view on the parasitism of the endophyte. In 1883 Kjellman described the following species:

Chlorochytrium inclusum Kjellman.—"In the vegetative stage spherical or subspherical, entirely included within the nurse plant, with the formation of the zoöspores becoming slightly elongated, short-conical, flask-shaped, ovoid or ellipsoidal, finally bare at the pointed apex, which penetrates the cortical layer of the nurse plant and emitting the zoöspores through an ostiole which has been formed." This species is endophytic upon *Sarcophyllis arctica*, mostly near the surface but sometimes in the middle of the host. It averages 80–100 mic., has yellowish-green contents and a cell-wall which is thin and of equal thickness. The chromatophore is thin and is spread along the wall. With the elongation at the formation of zoöspores the membrane thickens towards the outer surface especially, and a cone-shaped growth of cellulose is formed. The protoplasm then takes on a more intense yellow green and divides into numerous zoöspores. Numerous bulgings of the plant cell are produced probably by the growth of the surrounding tissues of the host. An ostiole is formed at the apex of the cellulose out-growth by which the zoöspores escape. Those cells found in the center of the host may attain as great a diameter as 275 mic. The even thickness of the wall of these cells suggests that they may be resting stages. Kjellman refers this plant to the genus *Chlorochytrium*, but hesitatingly on account of his lack of knowledge about the further development. He found *C. inclusum* in all of the *Sarcophyllis edulis* material which he has examined. Zoöspores are most abundantly produced in winter, but are also found in summer. The endophyte occurs in greatest abundance and most strongly developed in *Sarcophyllis arctica.* Its range is apparently coextensive with that of *Sarcophyllis arctica; i. e.*, throughout the arctic region, except in the North Atlantic, most abundant in the eastern part of the Siberian sea.

Three more new species were described by Schroeter in 1883. *Chlorochytrium rubrum* with red contents and occupying the air spaces of the leaves and stems of *Peplis portula* and of *Mentha aquatica; Chlorochytrium viride*, in the leaves of *Rumex obtusifolius;* and *C. lætum*, a spherical cell with yellow contents which become green in water, found in *Lychnis flos-cuculi.*

The investigations of Moore on *Chlorochytrium lemnæ* published in the following year brought to light no new facts of importance. Moore held that the nearest affinities of *Chlorochytrium* lie with *Protomyces.*

In 1887 Hieronymus described *C. archerianum* in punctured cells of *Sphagnum* leaves, and characterized by a greatly developed cellulose button. Zoöspores are formed regularly but do not copulate. P. Hariot, 1889, collected *C. inclusum* on species of *Gigartina* at Cape Horn, supposedly identical with Kjellman's *C. inclusum.*

In his Conspectus of Endophytic Algæ, Mobius, 1891, mentions in addition to those species enumerated above, *C. dermatocolax* which was described by Reinke and found on species of *Polysiphonia* and *Sphacelaria*, and in his opinion should be classified under the genus *Chlorocystis*, since it is marine, is intracellular and emits zoöspores singly.

C. schmitzii was described (1893) by Rosenvinge from Greenland material on *Cruoria arctica.* The cell is without a cellulose button or papilla, is more or less attenuate at the base and has a single chromatophore with sometimes two pyrenoids. Zoöspores were not observed.

Collections, Methods, etc.—Upon the *Constantinea* material which was collected by Miss J. E. Tilden at different points along Puget sound and was distributed as *Constantinea sitchensis* Post. and Rupr., were found a large number of endophytic unicellular, chlorophyllaceous algæ, referred to the genus *Chlorochytrium* of Cohn. The endophyte was found in abundance on all of the *Constantinea* collected. One collection was made in August, 1897, near Seattle, and in the summer of 1898 (May 25–July 2), five were made at as many points farther up the Sound. Most of the material used in the following investigations was fixed and preserved in a 2 per cent. sea-water solution of formalin. The green color of the endophyte was well preserved. The lower ends of the cells have in very many cases an irregular outline which may possibly be in part due to shrinkage but is caused for the most part by pressure of the surrounding *Constantinea* cells. In all of this endophyte formalin material and in the dried material as well, though not so markedly, brown bodies were found jutting out between the chromatophore and the cell wall and assuming various forms (see below). These bodies were undoubtedly due to a chlorophyllan reaction, the hypochlorin reaction of Pringsheim. The formalin solution when tested was found to give a slightly acid reaction.

Sections of *Constantinea* cut freehand between elder pith furnished most of the material for study. They were mounted either in the two per cent. formalin sea-water solution, in glycerine, or in glycerine jelly. Material carried through the usual paraffin method stained and mounted in Canada balsam has also furnished useful sections. The abundance of the endophyte makes it easy to get favorable surface and sectional views of it.

General Habit and Structure.—The endophytes on *Constantinea sitchensis* occur on both the upper and lower surfaces of the fronds. I have been unable to find any on the stipe. They are most abundant on the older fronds and especially towards the peripheral portion. From some young fronds they are almost altogether wanting. They occur in greatest numbers on the lower surface while rather few are found on the upper side. The following figures are taken from a medium-sized frond in the peripheral region: on the under side 140–160 (sometimes as many as 230) in one square mm.; on the upper surface 60–65 in the same area. Many areas of 4 square mm. on the upper surface contained no endophytes.

The endophytic cells are found almost exclusively in the tissues just beneath the pseudoepidermis of the nurse plant, with the slightly pointed end just at or just below the surface. They occur in rare cases in the central part of the frond completely enclosed. The pointed end protrudes from the tissues of the nurse plant in but few cases and then not more than for a distance equal to one-half the thickness of its outer wall. The cells not infrequently occur between the paraphyses of the nemathecia of *Constantinea* where they usually penetrate to but not into the tissues beneath.

The predominant form assumed by the endophyte is pear-shaped with the smaller end directed toward the surface of the nurse plant. The cells are often ovoidal and even ellipsoidal. In the central portion they assume a spheroidal form. In the paraphyses they become elongated or assume a figure-of-eight form similar to that described by Wright for *Chlorochytrium cohnii*. The inner ends of the cells are marked more or less by the bulgings undoubtedly caused by the pressure of the adjacent cells of the nurse plant.

The cells average 85–115 mic. in length and 40–85 mic. in breadth but often attain 143 x 100 mic. The wall in some cases is 28 mic. thick at the outer surface and 8 mic. thick around the remainder of the cell, but usually is less than one-half of these dimensions. The lamellation of the cell wall can clearly be seen in many sections (especially glycerine mounts) and is due probably to the apposition of successive layers of cellulose. Chlorophyll occurs in the form of a single yellowish-green plate in which are included a large number of fine refringent granules. This chromatophore extends around the entire wall of the cell and contains a varying number of very conspicuous pyrenoids, which are flattened spherical in form, 5–11 mic. in diameter, and jut out into the cavity of the cell. As many as thirty-nine have been found in a single cell and at least one pyrenoid can be seen soon after the cell begins to penetrate the tissues of the nurse plant. The pyrenoids show a clear central portion probably proteid. In sections stained heavily with aniline blue the central portion appears blue. Around the clear center are arranged 5–10 plates of starch which stain brown with both a KI and an alcohol solution of iodine. By careful washing of material stained in an alcoholic solution of iodine and with the aid of a $\frac{1}{16}$ oil immersion lens a distinct violet tinge is discernible in the plates. The protoplasmic contents of the cell are usually most dense in the pointed part. Between the chromatophore and the cell wall are found numerous rust-brown to black (in a few cases copper-colored) bodies of different form and size. In some places they occur in diffuse patches the limits of which are often indefinable, in others as five-pointed rosettes. Again they may appear filiform, partially and usually irregularly coiled or forming a delicate and loose network. I have interpreted these bodies as products of the action of the dilutely acid formalin solution and as identical with the hypochlorin of Pringsheim. His plates agree closely with much of the material at hand. In accordance with Pringsheim's account of the chemical reactions of hypochlorin, these brown bodies are wanting in those sections which have been carried through the alcohols in the method for paraffin embedding.

A large amount of material has been examined but in no case has even a trace of the production of zoöspores or gametes been found. The stages in the penetration of the nurse plant, consisting in the elongation of the at first spheroidal cell, the subsequent withdrawal of the protoplasm into the inner end and the increase in size of the latter to form the mature pyriform cell, have been observed, but nothing to indicate the formation of zoöspores.

Conclusions.—It is therefore upon the basis of vegetative characters that the endophyte described above is provisionally placed in the genus *Chlorochytrium* under *C. inclusum* Kjellman. Upon examination of the *Chlorochytrium inclusum* found upon *Dilsea* (*Sarcophyllis*) distributed in *Phycotheca Boreali-Americana* (Fasc. XI., no. 514) this is seen to possess a thicker cell wall than the material on *Constantinea sitchensis*, is almost spheroidal, larger, has denser dark green contents, contains no pyrenoids (or very inconspicuous, if present at all) and resembles a resting stage. The time of collection, December, moreover, strengthens this last supposition. The material under observation was collected, on the other hand, in summer, May to July. The light yellow-green color, the absence of reproductive bodies and the abundance of small cells point strongly, I think, to the conclusion that this endophyte is but a young stage of *Chlorochytrium inclusum* Kjellman. A similar difference in the vegetative and resting stages of *C. lemnæ* are recorded in Klebs' observations (*pl. 39, f. 2 and 9*). The form and habit of the endophyte upon *Constantinea* accord best with Kjellman's description of *C. inclusum*; no mention, however, is made by Kjellman of pyrenoids, which are so conspicuous in the *Constantinea* material. It is suggested by De-Toni and also by Miss Whitting that Kjellman's species may possibly belong to *Chlorocystis*, a genus established by Reinhard in 1885. *Chlorocystis* is described with but one pyrenoid while the endophyte on *Constantinea* contains many. *C. schmitzii*, described by Rosenvinge, is but imperfectly known. I have seen in the sections studied a number of cases where the endophyte in *Constantinea* has assumed approximately the same irregular or obovoidal form shown in the figures of Rosenvinge. The only remaining marine species of *Chlorochytrium*, *C. dermatocolax*, lives in the outer membrane of *Polysiphonia* and, according to Möbius, belongs probably to *Chlorocystis*.

The great similarity in vegetative structure to that described by Kjellman for *C. inclusum* would indicate that the *Constantinea* endophyte described above is a midsummer stage of *C. inclusum* and I would provisionally place it in that species awaiting further information on the life history and development.

BIBLIOGRAPHY.

Cohn, F. Ueber parasitische Algen. Remarks before the "Wanderversammlung der Schlesischen Gesellschaft für vaterländischer Cultur. Botanische Section. 1872. Beit. zur Biologie der Pflanzen. 1^2: 87. *pl. 2.* 1875.

Kny, L. Ueber eine grüne parasitische Alge. Sitz. Gesellch. natürf. Freunde zu Berlin. 1874.

Wright, P. On a new species of parasitic green alga belonging to the genus *Chlorochytrium* of Cohn. Trans. Roy. Irish Acad. **26**: 1877.

Szymanski, F. Ueber einige parasitische Algen. Inaug. dissert. der Univ. Breslau. 1878.

Kirchner, O. Die Algen Schlesiens. Breslau. 1878.

Klebs, G. Beiträge zur Kenntniss niederer Algenformen Bot. Centralb. **39**: 16–21. *pl. 3, 4.* 1881.

Hariot, P. Algues recuillies par la Mission scientifique du Cap Horn. Paris. 1882–83.

Reinke, J. Algenflora der westliche Ostsee deutschen Antheils. Sep.-Abdr. VI. Ber. Commiss. Untersuch. deutschen Meere, in Kiel. 1889.

De-Toni, J. B. Sylloge Algarum. **1**: 635–637. 1889.

Möbius, M. Conspectus Algarum endophytarum. Notarisia. **6**: 1282. 1891.

Rosenvinge, M. L. Kolderup. Les Algues Marines du Groenland. Ann. Sci. Nat. Bot. **19**: 169. *f. 56*. 1894.

Whitting, F. G. On *Chlorocystis sarcophyci*. Phyc. Mem. Pt. 2. 41–45. 1893.

Wille, N. Die natürlichen Pflanzenfamilien. I. Abt. 2. 66. *f. 42*. 1897.

Schaarschmidt, G. A *Chlorochytrium Erdelylen*. Magyar Növenyt. Lapok. **5**: 37. 8181.

Kjellman, F. R. Algæ of the Arctic sea. 320. *pl. 31. f. 8–17*. 1883.

Schröter, J. Neue Beiträge zur Algenkunde Schlesiens. 61. Jahresb. Schles. Gesellch. Cult. 178–189. 1883.

Moore, S. Le M. Remarks on some endophytic Algæ. Journ. of Bot. **22**: 136–138. 1884.

Lagerheim, G. On *Chlorochytrium cohnii* Wright och ders förhâllande till närstânde arter. Sv. V. A. Oefvers. **7**: 91–97. *pl. 1*. (Bot. Jahres. **12**^{1}: 371. 1886.)

Hieronymus, G. Ueber einige Algen des Riesengebirges. Jahresb. Schles. Gesellch. Vaterl. Cultur. 293–297. 1887.

Tilden, J. E. American Algae. Cent. III. 1898.

Description of Plate XIX.

1. Diagram of a cross section of a frond of *Constantinea sitchensis* showing the endophytic *Chlorochytrium* cells on the upper (less numerous) and lower surface. *e.* endophyte. *p.* pseudoepidermis. *i.* intermediate area. *c.* central area of the frond.

2. Surface view of the frond of *Constantinea* (lower surface) showing the pseudoepidermis (*p*) with cavities (*e*) through which the endophytes have penetrated. x 57.

3, 4, 5, 6. Stages in the penetration of the nurse plant. *s.* pyrenoid. x 288.

7. *Chlorochytrium* cell with a not infrequent form. Shows filamentous form of hypochlorin. x 288.

8. Cell showing elongated form of endophyte found amongst the paraphyses of the nurse plant. x 288.

9. Large *Chlorochytrium* cell of typical form. x 288.

10. Detail showing the position of a *Chlorochytrium* cell in the cross section of the *Constantinea* frond. Letters as in no. 1. x 288.

11. The outer end of a *Chlorochytrium* cell showing the lamellation of the cell wall. x 288.

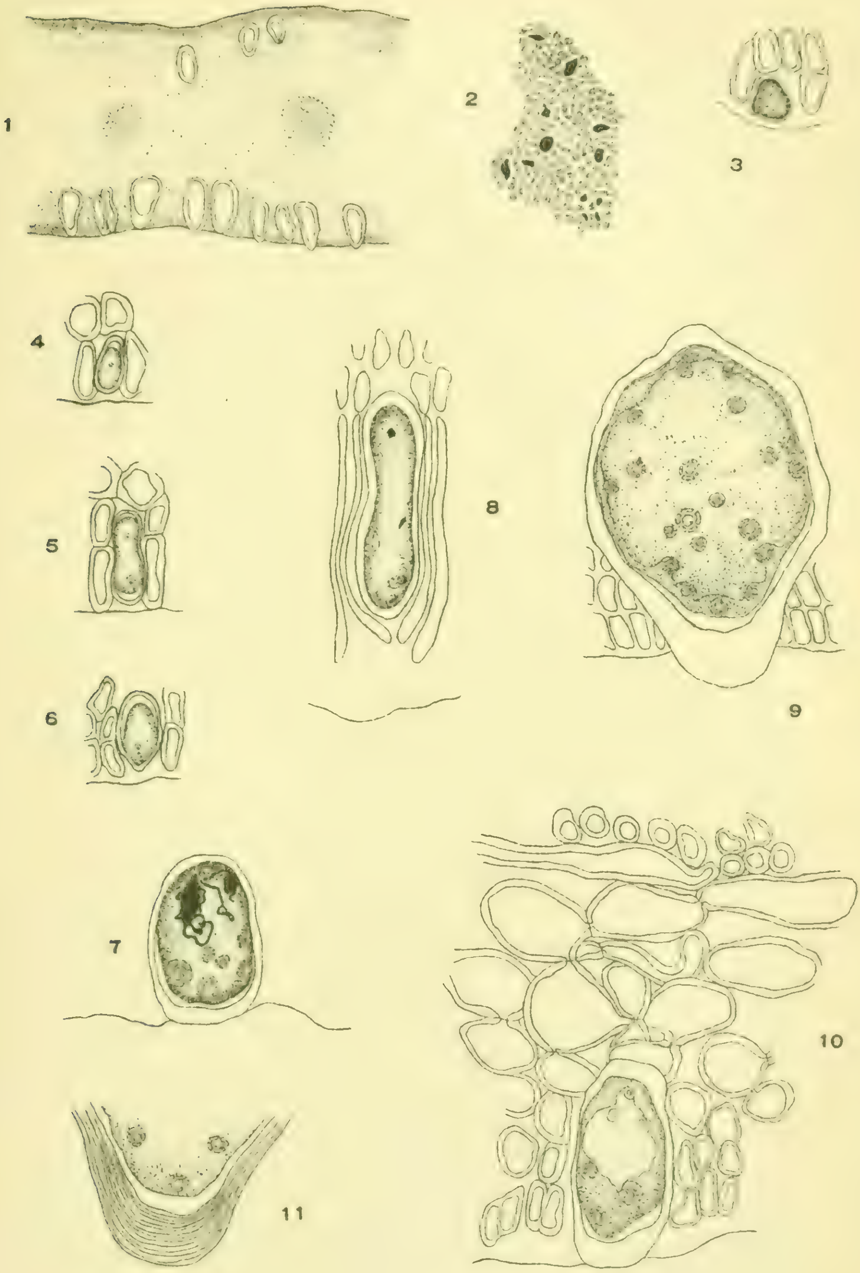


PLATE XIX.

THE HELIOTYPE PRINTING CO., BOSTON.

XVII. OBSERVATIONS ON RHODYMENIA.

FREDERIC K. BUTTERS.

History and Literature. — The genus *Rhodymenia* was founded by Greville in 1830. As originally constituted it contained species which have since been referred to *Gracilaria*, *Gigartina*, *Kallymenia*, *Calliblepharis* and other genera. Agardh (3), p. 376, states that in his Mediterranean Algæ (1) he transferred many species to the genera *Gracilaria*, *Gigantina* and *Kallymenia*, but united *Calliblepharis* with *Rhodymenia* under the latter name. In 1849 Kützing in his Species Algarum, p. 778, united the species of the genera *Rhodymenia* and *Gracilaria* together with some other species under the generic name *Sphærococcus*.

Agardh (2), p. 15, (3) p. 375, revised the genus *Rhodymenia* and gave it substantially its present limits and generic characters. The generic description as given by De-Toni and Levi, p. 19, is as follows: Frond plane, membranaceous, dichotomous or palmate, proliferate from the margin or surface, composed of two layers; interior cells oblong, cortical minute, rounded; cystocarps scattered throughout the frond, each within an hemispherical pericarp opening by a carpostome, composed of cells, the outer radiating the inner concentric; cystocarp with a simple rounded or somewhat lobed nucleus; nucleus naked within the pericarp, on a basal placenta with paniculate-branched placental filaments sustaining the lobes; young fertile lobes disposed radially composed of articulated filaments, older obconico-rotund, bearing numerous protospores; tetraspores often collected into sori, cruciately divided; antheridia produced in superficial sori composed of minute hyaline cells in a single vertical series.

Greville spelled the name of this genus *Rhodomenia*. Montagne, p. 44, in 1839, employed this spelling in a list of Brasilian cryptogams, but in a footnote states that, in conformity to its etymology it should be spelled *Rhodymenia*. J.

Agardh (3) adopted the latter spelling and it has since been in general use, although *Rhodomenia* and, according to Ardissone, *Rhodhymenia* and *Rodhymenia* also have been occasionally employed.

Rhodymenia pertusa was first described and figured by Postels and Ruprecht, p. 20, *pl. 36*, under the name *Porphyra pertusa*. Kützing, p. 693, describes it under this name. He introduces a question, however, in respect to its generic determination. J. G. Agardh (3), p. 376, points out that the species should be classed as a *Rhodymenia* and not as *Porphyra*. He describes it as *Rhodymenia pertusa* (Post. and Rupr.) and places it, together with *Rhodymenia palmata* (Linn. Sp. 2: 1630) and *Rhodymenia peruviana* (J. Ag. Mscr.) in the section *Palmatæ* characterized by "tetraspores occurring throughout the surface of the frond, scattered or collected into sori." In his Epicrisis (Agardh, J. G. (4), p. 379), he assigns it the same position.

Agardh (3) gives the habitat of *Rhodymenia pertusa* as "in the Arctic Ocean near Kamtschatka (Mus. Petropolitani!); and near Greenland (Wormskjöld!)." Kjellman reports it it from the northwest coast of Spitzbergen and the west coast of Greenland. It was first reported from the northwest coast of America by Harvey (1) who found it among the algae collected by Captain Wilkes' exploring expedition. Harvey gives its locality as the Straits of St. Juan de Fuca. He compared Wilkes' specimens with an authentic specimen furnished him by Dr. Ruprecht and found them identical in species, though Wilkes' specimens were considerably larger than Ruprechts's. Harvey, p. 171, also reports the species as collected by Dr. Lyall in 1859–61, his specimens being "cast ashore on Point Roberts, and on rocks at low water, Fuca Strait." Cystocarps were present on both sets of specimens mentioned by Harvey. In commenting on the specific name, Harvey (1) p. 148, states that to him the perforations of the thallus appear to be due to casualties.

In 1893 Carruthers, p. 80, examined one of the specimens mentioned by Harvey as collected by Dr. Lyall. He found that in that specimen the cystocarps occur all over the much perforated segments: the majority are very young and project but little from the surface of the thallus. The structure of the thallus is that typical of the genus. He says "The cystocarp projects on one side of the thallus and possesses a fairly thick fruit wall of five or six cells in thickness arranged irregularly inwards. At the bottom of the fruit cavity is to be found the placenta formed of numerous small cells closely packed together and lying on the medullary layer of large cells.

"From the placenta the gonimoblast of more or less irregular shape, is borne on an elongated style cell and spreads upward into the empty fruit cavity.

"This gonimoblast is composed of numerous pear-shaped lobes which lie close together. The spores of these lobes become ripe nearly at the same time.

"The ostiole is generally quite in the center of the projecting fruit wall, and is similar to the ostioles of the kindred species."

Collection and Preservation.—All the material at hand was collected by Miss Josephine E. Tilden at Port Orchard, Kitsap County, Washington, on August 2, 1897. The specimens were dredged in water 4–6 fathoms deep. A small portion of the material was killed and preserved in 80 per cent. alcohol. The larger part of the material was dried. By soaking, this dried material so far regained its original form that the anatomy could be well studied although the cell contents were largely disorganized. All the observations upon the stipe and the proliferations were made upon this dried material; observations upon other points were made mainly upon the alcoholic material.

Methods.—The dried material was soaked in water until it regained its natural consistency. Various methods were employed in cutting the tissues. Much of the material was cut upon the Osterhout freezing chamber. (Osterhout, W. J. V., p. 195.) The alcoholic material was first passed into water —preferably through about three intermediate grades of dilute alcohol. When the alcohol was completely removed the material was in some cases infiltrated with gelatine solution and then mounted in a drop of gum arabic solution upon the freezing chamber; in other cases it was embedded directly in the gum arabic. On account of the firm nature of most of the tissues, this method of mounting directly in gum arabic proved quite as successful as that in which the tissues were first infiltrated with gelatine.

The sections, as soon as they were removed from the knife, were passed into 20 per cent. glycerine. Those which were to be stained were transferred from this glycerine to the staining solution, thence, after washing, back to the glycerine solution. The glycerine solution was allowed to concentrate by evaporation, and the sections were thence mounted into glycerine jelly. Portions of the frond were also embedded in pith and cut freehand with the razor.

Some of the material was embedded in paraffine, according to the usual methods and cut on the microtome. The sections thus obtained proved, in some instances, very successful, especially in the case of such firm tissues as the stipe and the vegetative portions of the lamina.

Several staining fluids were used. Both section-staining and staining *in toto* were employed. The former method proved most successful. The following stains were found useful.

Aniline blue: Sections were placed for 5–10 minutes in a saturated solution of aniline blue (spiritlös) in 50 per cent. alcohol. The walls were stained a deep blue, gelatinous structures and cell contents a light blue. This proved the most useful stain for clearly defining anatomical details.

Hoffman's violet: Sections were stained with a saturated solution of Hoffman's violet in concentrated sulphuric acid. As soon as the section had taken a brown stain they were placed in water and the acid washed out. The protoplasm took a blue stain, the walls were unstained. This method proved useful in staining the protoplasmic connections between the cells.

Fuchsin: Dilute alcoholic solution of fuchsin stained the walls light red, the protoplasmic contents a deeper red.

Iodine in potassium iodide: This stained the floridian starch a dark yellow-brown, the other cell contents a light yellow-brown. It proved very useful in staining the protoplasmic connections between the cells, especially in the gonimoblast filaments.

Gross anatomy (Fig. 1).—The plant consists of a broad, flat, membranaceous, more or less subdivided, blood-red lamina borne upon a short stipe which is sensibly continuous with the lamina. The stipe is expanded below into a small holdfast. The lamina is sometimes nearly entire in outline, ovate, or broadly lanceolate, sometimes very deeply lobed, or divided almost to the base into 2–4 lobes which may be widely divergent. The lamina is 17–40 cm. long and 8–17 cm. wide. The two faces of the frond are in all respects similar. The lamina is perforated by numerous holes ranging from .5 mm. to 10 cm. in length and from .5 mm. to 2 cm. in width. The smallest are almost circular in outline. Those somewhat larger (up to about 5 mm. in diameter) are usually somewhat oval, being elongated in the direction of the long axis of the frond. The larger perforations are of irregular elongated outline. Sometimes these perforations are exceedingly numerous, as many as four or five per square cm. being not uncommon.

In some specimens numerous proliferations are borne on the faces and edges of the lamina and also on the stipe. These are cylindrical bodies, about 1 mm. in diameter, seldom more than 25 mm. long, often flattened somewhat towards the apex and often branched once or twice or deeply lobed at the apex.

In two specimens the upper portions of the laminæ present a peculiar mottled appearance which was at first supposed to be due to the presence of tetraspores. It appears that this is not the cause of the phenomenon noted. This subject will be discussed further under the description of the cystocarp.

The entire stipe was present in only one of the specimens at hand. In this it was 3.5 cm. long, about 1 mm. in greatest diameter, flattened somewhat, parallel to the flat surface of the lamina, passing insensibly into the lamina above, and expanding abruptly below to form the holdfast, which is a small, thin, irregular disk, about 5 mm. in diameter.

All of the specimens have cystocarps scattered irregularly over the entire surface of both sides of the lamina. These are bodies 1–1.5 mm. in diameter, nearly hemispherical, or protruding slightly at the apex, and are extremely numerous, as many as fifteen being often found on one square cm. of the lamina.

Minute anatomy: Lamina.—The lamina consists of pseudoparenchymatous tissue of which two principal areas may be distinguished in the cross-section (a), a central layer of large-celled; and (b) a cortical layer of small-celled tissue (Fig. 2).

(*a*) The cells of the central area are large, generally somewhat flattened parallel to the surface of the frond, isodiametrical in tangential section (Fig. 3). The cells vary greatly in size, the average being 73.5 x 105 mic., while cells occur as small as 6 x 14 mic., and as large as 100 x 200 mic. The largest cells are situated near the central portion of this area, and from them the size of the cells decreases quite regularly towards the more superficial portions. The more superficial cells of this area differ considerably in other respects also, from the central cells. The outer cells are more flattened than the central ones, they are more densely protoplasmic and are filled with grains of floridian starch, while but little starch occurs in the central cells. In this more superficial portion of the central area the protoplasmic connections between the cells of the filaments of which the tissue is composed can be easily made out. They are plainly visible in both stained and unstained preparations, and in both tangential and cross sections. In accordance with the less dense protoplasmic contents of the central cells, the connecting strands are less evident among them, but when the walls of this area are stained, numerous pits are shown penetrating the walls of the central cells (Fig. 3). These pits appear to be of irregular distribution and often more than one are to be observed between the same pair of cells. They can be best observed in a tangential section.

(*b*) The cortical area consists of small cells almost spherical or with the longest diameter perpendicular to the surface of the frond, of quite uniform size (averaging 5.7 x 8.5 mic.), arranged in 1–3 layers, either in filaments perpendicular to the surface of the frond or somewhat irregularly. In a surface view of the lamina they appear entirely irregular in arrangement (Fig. 4). The cells are densely protoplasmic and contain chromatophores.

Stipe.—The general structure of the stipe (Fig. 5) is similar to that of the lamina, but there are numerous special modifications of the several areas. The cells of the central area are elongated somewhat in the direction of the axis of the frond and are somewhat compressed parallel to the compression of the stipe. They are of more uniform size than were those of the lamina, and they were otherwise more nearly uniform than those of the lamina. Their average size is 57 x 86 x 143 mic. The cortical area of the stipe is much thicker than that of the lamina. It is 3–8 cells deep. The cells are larger than the corresponding cells of the lamina (average 14 x 23 mic.) and are conspicuously arranged in filaments running perpendicular to the surface of the stipe.

Proliferations.—The structure of the proliferation is similar to that of the main frond. The central cells are somewhat elongated in the direction of the axis, and, in general, are more numerous and smaller than the corresponding ones of the main frond. All the cells except those of the cortical area contain considerable floridian starch.

Reproductive tract.—Cystocarp (Fig. 7–12). The cystocarp projects on one side of the thallus. The pericarp is composed of thickened cortical tissue, which, in the mature cystocarp, is 8–40 cells thick. The outer walls of the pericarp are small and resemble those of the cortex of the vegetative part of the frond. The inner cells are large (14 x 29 mic.), flattened parallel to the surface of the cystocarp and show numerous irregular protoplasmic connections. The cystocarp opens by a carpostome situated at the apex of the pericarp.

The sporogenous tissue is in the form of an irregularly lobed mass, borne on a basal placenta, and partially filling the cavity of the cystocarp. The space between the spore mass and the pericarp is filled with gelatine. The placenta is a mass of small-celled tissue containing numerous intercellular spaces, which rests upon the large-celled central tissue of the lamina. The gonimoblast filaments (Fig. 9–11) branch repeatedly. They consist of irregular elongated or rounded, often club-shaped cells, with dense, finely granular protoplasm and very transparent walls. They contain no starch. They are connected in filaments by very broad protoplasmic connections surrounded midway by a callous-like ring. The upper cells of the filaments are smaller and more rounded than the lower. The structure of the filaments was best shown in preparations made by pressing out the contents of a mature cystocarp upon a microscopic slide, staining lightly with iodine in potassium iodide, and then pressing out with a cover glass. The spores themselves are irregular, ovoid, thin-walled cells, densely packed with floridian starch. Their average size is 21.5 x 34.5 mic., but they vary considerably in this respect. The number of spores produced in each cystocarp is very great, 20,000–30,000 being not uncommon. The lowest lobes of the sporogenous mass appear to be in all cases sterile. They form small masses of compact tissue consisting for the greater part of cells having about one-half the diameter of mature spores and containing but little starch. A few long cells like those of the gonimoblast filaments also occur in this region.

In many cystocarps branched filaments of cells rise from the vegetative tissue at the base of the cystocarp. The cells of these filaments (Fig. 8) exhibit peculiar lateral outgrowths which appear to fuse with the adjacent cells or with similar outgrowths from them, forming a peculiar loose, irregularly connected tissue similar to that which forms the inner portion of the cystocarp wall. These filaments are not present in all cystocarps. They appear to result from the tearing of the subcortical tissue in the formation of the cavity of the cystocarp.

In the young cystocarp (Fig. 12) the thickened wall is already present and shows its permanent division into two layers. The cells of the outer layer are arranged in filaments perpendicular to the surface, those of the subcortical layer are arranged in oblique rows converging towards the apex of the pericarp. The placental area and spore mass are represented by a few connected cells with very dense contents. The cavity of the cystocarp is, at this stage, comparatively small. The carpostome is already developed even in very young cystocarps. It appears to be formed by the tearing apart of the cells together with the destruction of some of the cells. As was mentioned in the account of the gross anatomy of the lamina, in two specimens the apical portions of the frond present a peculiar mottled appearance. Cross sections of these areas show that in places there are slight protuberances from the surface of the thallus associated with an unusual development of cortical and, in some cases, also of the subcortical cells. The cortical cells are rather narrower than elsewhere, and more elongated perpendicularly to the surface of the frond. The cortical layer is also a greater number of cells deep than elsewhere, and in some cases there is also increase in the number of the smaller central cells situated immediately beneath the cortex.. These areas in some cases involve only a few cells, in others they are .5 mm. in diameter. The structure of the larger protuberances agrees essentially with that of the young cystocarp described above, except that in no cases could any cavity be discovered in them. They appear to me to be very young stages of cystocarp development, but in no case could positive evidence of their nature be discovered.

No indubitable cases of tetraspore formation were seen, but in some cross sections taken through the upper part of the lamina, some of the cortical cells are peculiarly divided producing somewhat the appearance of tetraspore formation (Fig. 6). Except for their peculiar arrangement, these cells appear in all respects similar to the ordinary cortical cells. Whether they are tetraspores or not, could not be determined. Their method of division is cruciate or somewhat irregular approaching the tetrahedral arrangement.

Bibliography.

Greville, R. K. Alg. 1830.

Montagne, C. Crypt. Brasil. in Ann. Sci. Nat. Bot. II. **12**: 42–55. 1839.

Postels A. and Ruprecht, F. J. Illust. Algar. 20. *pl. 36.* 1840.

Kützing, F. T. Spec. Algar. 693, 778–784. 1849.

(1) Agardh, J. G. Alg. Med. et Adriat. 1842.

(2) Agardh, J. G. Alg. Liebm.

(3) Agardh, J. G. Spec. Gen. et Ord. Algar. **2**: 374–383. 1852.

(4) Agardh, J. G. Epicr. syst. Florid. 324, 329. 1876.

Harvey, W. H. Ner. Bor.-Am. **2**: 147, 148. 1853.

Harvey, W. H. Coll. Algæ Northwest Coast of North America. in Journ. Linn. Soc. Bot. **6**: 157–177. 1862.

Kjellman, F. R. Alg. Arctic Sea. 150, 151. 1883.

Ardissone, F., Phyc. Med. **1**: 212–215. 1883.

De-Toni, J. B. and Levi, D. Schem. Gen. Florid. Illustr. Notarisia. **3**: appendix I–XXV. 1888.

Carruthers, J. B. On the cystocarps of species of *Callophyllis* and *Rhodymenia*. Jour. Linn. Soc. Bot. **29**: 77–86. 1893.

Osterhout, W. J. V. A simple freezing device. Bot. Gaz. **21**: 195–201. 1896.

Description of Plate XX.

1. Mature plant showing perforations, proliferations and cystocarps. x $\frac{1}{8}$.

2. Cross section of frond. *Med.* medullary area, *cor.* cortical area. x 112.

3. Longitudinal section of central area of frond, showing pits in the walls. x 132.

5. Surface view of frond, showing irregular arrangement of surface cells. Stained with fuchsin. x 335.

5. Cross section of stipe. Drawn with camera lucida. x 40.

6. Tetraspores ? x 335.

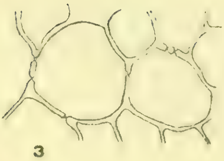
7. Cross section of mature cystocarp (not cut through carpostome) showing placentation and general structure of the spore mass. The upper part of the spore mass is somewhat scattered. Only the spores have their contents filled in. x 39.

8. Peculiarly branched and interwoven filaments from the base of a cystocarp. x 237.

9. Gonimoblast filaments stained one minute in iodine in potassium iodide. x 237.

10, 11. Gonimoblast filaments, contents not drawn. x 237.

12. Young cystocarp showing carpostome and early stage in the development of spore mass. Contents have been omitted except from sporogenous cells. Drawn with Camera lucida. x 230.



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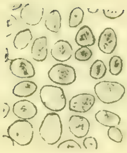

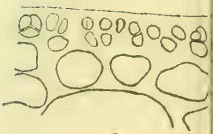

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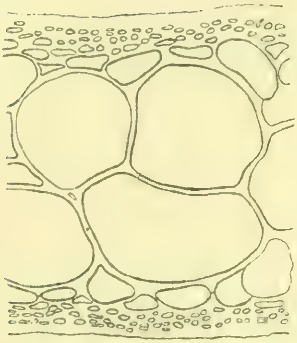

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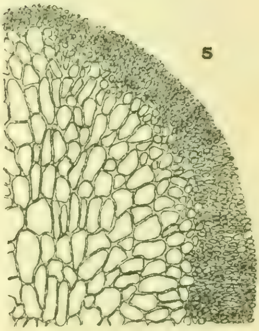

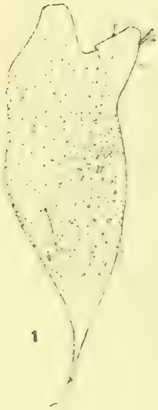

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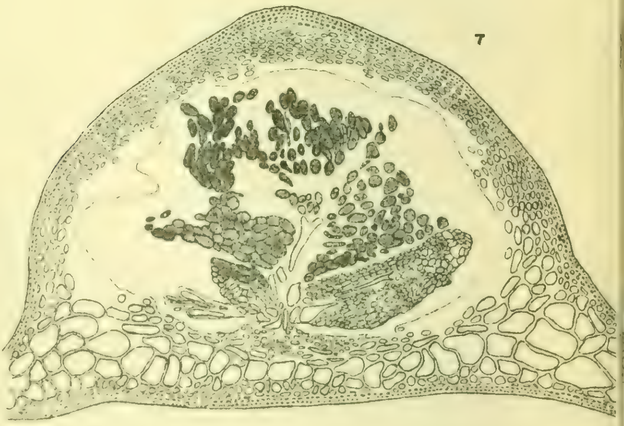

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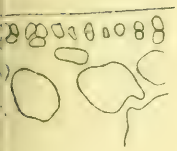

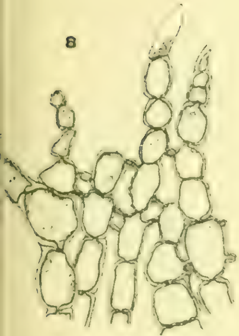

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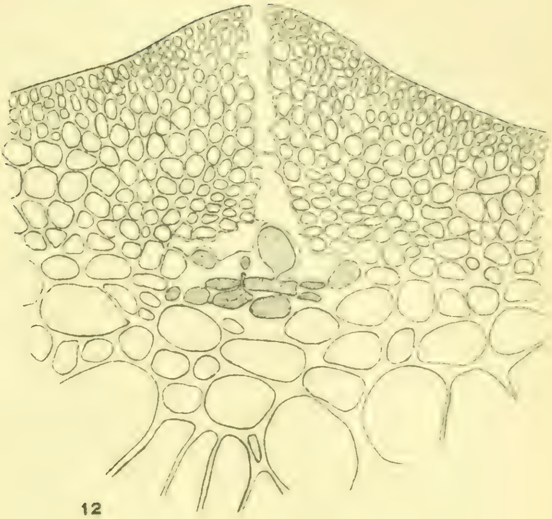

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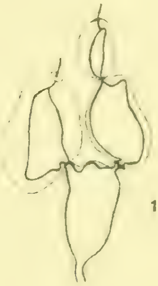

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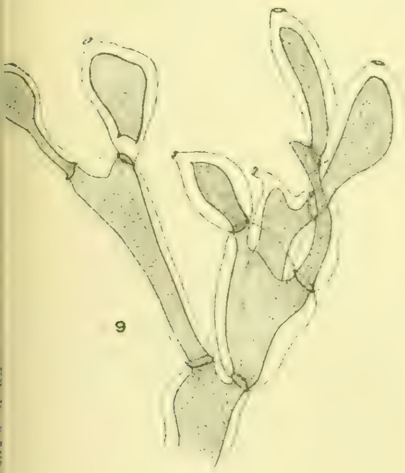

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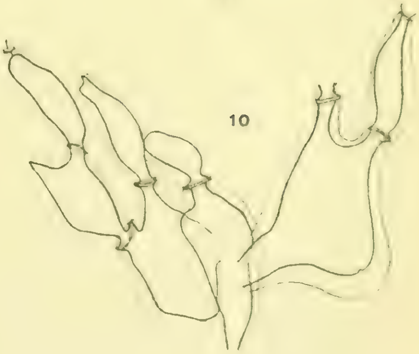

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E XX.

TING CO., BOSTON.

XVIII. CONTRIBUTIONS TO A KNOWLEDGE OF THE LICHENS OF MINNESOTA.—IV. LICHENS OF THE LAKE SUPERIOR REGION.

BRUCE FINK.

CONSIDERATIONS OF DISTRIBUTION AND HABITAT.

The area treated in this paper includes essentially the counties of Cook and Lake, comprising about 5,000 square miles of land. It lies to the northwest of lake Superior, bordering on the lake for about 150 miles and on the province of Ontario, Canada, for about 125 miles, thus forming the extreme northeastern portion of the State of Minnesota. It was supposed, before studying it, that the region, because of its position, would furnish many lichen species new to the State and to the interior of North America, and the investigation has fulfilled expectations. Besides its geographical position, certain physical features have produced diversity of lichen species as will be shown later.

The lichens of the region have never been studied previously. Tuckerman, in his Synopsis,* mentions collections from the north shore of lake Superior by John Macoun and L. Agassiz. The collections by Agassiz were made in 1848 and published † from 1850 to 1852. He traversed the north shore from Sault Saint Marie to Fort William. The collecting by Macoun was done in July, 1869, along the north shore in Canada, and in 1884 around lake Nipigon. A publication may soon be expected from the latter collector, giving a complete list of the Canadian lichens, and this should add much of interest concerning some species listed in this paper. Of the two collectors, Agassiz, at Fort William, came within about 50 miles, while Macoun probably came within 150 miles of certain points reached by me along the international boundary or the shore of the lake.

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* Tuckerman, E., Synopsis of the North American Lichens, Parts I and II, 1882 and 1888.

† Agassiz, L., Lake Superior, its Physical Character, Vegetation and Animals compared with those of other and similar Regions, pp. 170–174. Boston, 1850.

Several species of the lichens collected by Dr. C. C. Parry in 1848 and published in 1895 * show northern range, but careful investigation † indicates that they were collected south of lake Superior. Thus it appears that the collections listed herein are the first made on the north shore of lake Superior in Minnesota, or along the international boundary for more than 100 miles west of the lake.

The collecting was done by the writer, assisted by Mr. A. S. Skinner, during the latter part of June and the whole month of July, 1897. We were fortunate enough to be associated with Dr. A. H. Elftman, who wished to traverse the region for geological study and whose thorough knowledge of the territory covered, alone made it possible for us to find the best collecting stations in this for the most part uninhabited region, and thus to accomplish good results in a comparatively short time.

We reached Grand Portage island on the north shore of lake Superior, June 16th, and began collecting at once. The plan was to study the lichen flora of the international boundary and the north shore of lake Superior within the boundaries of Minnesota and to reach some of the inland portions of the two counties. On the whole trip we sought localities as collecting stations offering the greatest differences as to elevation, rock formations, arboreal flora, soil, moisture, etc. Beginning at Grand Portage island we traveled westward by Pigeon river and the chain of lakes along the international boundary to Gunflint, thence south by a series of lakes to Poplar river and down the river to Lutsen, on the shore of lake Superior. From here we proceeded down the lake to Tofte, Beaver Bay and Two Harbors. We next went directly to Ely and thence eastward to Snowbank lake. We made as thorough a study as possible of the lichen flora of the Grand Portage area, and then stopped for study whenever and wherever we found enough of difference in

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* Fink, B., Lichens collected by Dr. C. C. Parry in Wisconsin and Minnesota in 1848. Proc. Iowa Acad. Sci. 2 : 137. 1895.

† Parry, C. C., Systematic Catalogue of Plants of Wisconsin and Minnesota, made in connection with the geological survey of the Northwest during the season of 1848. In Owen, D. D., Report of a geological survey of Wisconsin, Iowa, Minnesota and incidentally of a portion of Nebraska Territory. Appendix, article V. 606–622. 1852, mentions *Cladonia rangiferina* (L.) Hoffm. and *Gyrophora muhlenbergii* Ach. from Falls of St. Croix.

physical environment to lead to the conclusion that time would be profitably employed.

The writer was relieved of camp duty as much as possible, so that there was some time for collecting each day, even when traveling. However, the few collections thus made are nearly all recorded in the list with those of the nearest well studied locality. The principal collecting stations are given below, with elevation and time spent in collecting for each. Since many of these stations are in uninhabited and little known regions, I have given the township and range of each one.

I. Grand Portage and Grand Portage island, 9 days, elevation 602 to 1305 feet, T. 63 N., R. 6 E.

II. English portage, 3 hours, elevation 1339 feet, T. 64 N., R. 4 E.

III. South Fowl lake, 3 hours, elevation 1436–1450 feet, T. 64 N., R. 4 E.

IV. Moose lake, 2 hours, elevation 1492 feet, T. 65 N., R. 3 E.

V. Rose lake, 1 day, elevation 1528 feet, T. 65 N., R. 1 W.

VI. Paulson iron mines, 2 days, elevation 1825 to 2000 feet, T. 65 N., R. 4 W.

VII. Gunflint, 1 day, elevation 1547 to 1650 feet, T. 65 N., R. 3 W.

VIII. Winchell lake, 2 days, elevation 1910 to 2230 feet, T. 64 N., R. 2 W.

IX. Brule lake, 5 hours, elevation 2084 feet, T. 63 N., R. 3 W.

X. Tofte, 3 days, elevation 927 to 1529 feet, T. 59 N., R. 4 W.

XI. Beaver Bay, 2 days, elevation 602 to 1250 feet, T. 55 N., R. 8 W.

XII. Great Palisades, 6 hours, elevation 602 to 1200 feet, T. 56 N., R. 7 W.

XIII. Two Harbors, 2 hours, elevation 692 feet, T. 52 N., R. 11 W.

XIV. Prairie portage, 1 day, elevation 1300 feet, T. 64 N., R. 9 W.

XV. Iron Mountain lake, 1 day, elevation 1342 feet, R. 64 N., R. 8 W.

XVI. Snowbank lake, 4 days, elevation 1424 feet, T. 64 N., R. 9 W.

XVII. Disappointment lake, 1 day, elevation 1449–1850 feet, T. 64 N., R. 8 W.

XVIII. Moose lake, 1 day, elevation, 1339 feet, T. 64 N., R. 9 W.

XIX. Wind lake, 1 day, elevation 1359 feet, T. 64 N., R. 9 W.

XX. Ella Hall lake, 3 hours, elevation 1306 feet, T. 64 N., R. 10 W.

XXI. Fall lake, 3 hours, elevation 1313 feet, T. 63 N., R. 11 W.

Of the stations given above, numbers XIV to XIX inclusive have been designated in the list of species as the Snowbank lake area, XX and XXI as Ely, VIII and IX as the Misquah hills, and VI and VII as Gunflint. All other areas include each but a single station. The quantity-collecting being largely done when we left Grand Portage, we were able to move rapidly, as only plants not found in this first area needed to be collected in bulk. For illustration of distribution, the collections were made as complete as possible at Grand Portage, Gunflint, in the Misquah hills, at Tofte, at Beaver Bay and in the Snowbank lake area.

There is an appreciable difference between the lichen flora of Grand Portage island and that of the mainland two miles across the bay. The island reaches an elevation of only 125 feet above lake Superior while Mt. Josephine on the mainland reaches an altitude of about 800 feet above the lake. The Keweenawan series of rocks, which appears on the island, is wanting on the portion of the adjacent mainland explored, while the Animikie series is found in both places. However, I could not ascertain that difference in petrographical construction in any noticeable way determines the floral differences either here or elsewhere in the territory studied. Passing by the Gunflint area for the present, I may say that the Misquah hills were regarded as especially important, since they contain the highest areas in the state, and were as carefully studied as our time would permit. Carlton peak at Tofte, and the Palisades were points of special interest. Two Harbors was of interest as it is the most southern point reached in the survey, and Ely was, also, as it is the most western. However, the Snowbank lake area somewhat further east was much more thoroughly studied than Ely.

On the whole all of the two counties was studied thoroughly enough to know that practically all of the lichens generally distributed over the area were secured as well as many more which as yet show only local occurrence. Examination of the route will show that we covered all of the international boundary between Ely and Grand Portage, except about 20 miles in a straight line from the most eastern portion of the Snowbank lake area to Gunflint. Thus the boundary was well studied. The line of travel through the Misquah hills from Gunflint to Lutsen gave a fair view of the interior of the region as well as the highest area in the state. A day spent along the shore at Lutsen failed to furnish any species not found at Grand Portage. Consequently, as we were to stop at Tofte, only 10 miles distant, no record was made of the species found at the former place. Tofte, Beaver Bay and the Palisades gave a good view of the lake shore and higher elevations near by in the Sawteeth mountains. It is to be regretted that we did not have opportunity for examination of the lake shore and Sawteeth mountains at some points between Lutsen and Grand Portage, but doubtless the number of additional species would not have been large after a thorough examination of the shore both to the extreme north and toward the south of the area studied.

The whole region is one of extreme interest to the lichenist because of the diversity of natural conditions which gives a flora rich in individuals as well as variations within certain species which attracted special attention. The great masses of igneous and metamorphic rocks along the Superior and inland shore lines, the same rocks back from shore lines and the coniferous and various other trees together with diversity as to temperature, moisture and elevation, all help to produce a flora richer in lichen species than I had expected to find. Though the annual precipitation of moisture for the area is not large, yet the comparatively impervious nature of the rocks causes the water to collect in depressions of surface, forming a multitude of lakes of various sizes whose moist borders are a veritable paradise for lichens and especially for lithophytic species. The dense forests also hold moisture and favor lichen growth. When one finds single branches of *Usnea longissima* Ach. five feet long, as we collected on Grand Portage island, he realizes the significance of the name. Here and in some other localities of the region studied the dying conifers especially are literally covered with this plant, other species of the genus and *Alectoria jubata* (L.) Nyl., all growing in a tangled profusion which obscures the host and when wet with rain or dew furnishes a view of surpassing beauty. Hardly less remarkable is the growth of *Cladonia rangiferina* (L.) Hoffm. in open woods near Mt. Josephine, single clusters measuring three or four feet across and reaching a foot in height. This plant was also common on rocks and in crevices exposed to wind and sun, but was always much smaller in such locations. It is evidently not a natural pioneer among lichens, but grows after other plants have attacked the rocky substratum, or on a thin layer of soil in crevices, and best of all after trees or shrubs have grown sufficiently to protect it somewhat from wind and sun and have not yet become large enough or thick enough to kill it out. This same kind of ecological relation favors *Cladonia furcata* (Huds.) Fr., a variety of which was found fruiting only in such environment. More is given below about other *Cladonias*, and the observation could be extended to *Stereocaulon*.

After fires have passed over a region destroying the trees and small scattered second growth begins to appear to furnish some protection, *Cladonia cristatella* Tuck. and a large variety of forms of *C. gracilis* (L.) Nyl. soon begin to grow in great profusion on old stumps, prostrate logs and bits of decaying wood lying upon, or more or less sunken into the soil. Only a few of the many varieties of the latter plant allowed by European lichenists are recognized in the list of species though forms closely resembling other varieties, so called, are represented in my collections. Nothing seems to be gained by carrying the "splitting" process to extremes without a study of life histories. *C. gracilis* (L.) Nyl. in regions recently burned showed much less variation than in places where the species had been established longer since the burning, and a careful study of a large number of individuals in this region, extending over a series of years would enable one to trace the growth and variation within single individuals and thus establish varieties with certainty. Great variety was observed in the plants in regions that had burned 15 or at most 20 years ago so that a study extending over 10 years should be sufficient to give the desired data.

Like *Cladonia rangiferina* (L.) Hoffm., *C. cristatella* Tuck. is extremely sensitive to environment. In regions where the plants are exposed to sun and wind and in stations of high elevation, the plants are much smaller than in better shaded and less elevated places. The relation of size to amount of protection offered by trees and shrubs may be observed in many places between Gunflint and Lutsen, especially at Gunflint and in the Misquah hills. The effect of elevation, or rather the combined effect of elevation and exposure, was especially noted on Mt. Josephine and on Carlton peak. In both of these places the stunted condition was also noticeable in other *Cladonias* and in lichens belonging to other genera.

The part that lichens play in rock decay and soil formation was studied in a general way in the Grand Portage area, and some of the most noticeable facts are stated below. Grand Portage island contains 57 acres of land and furnishes sufficient variety as to substrata suitable to lichen growth to make the study interesting. The crustaceous lichens furnish most of the species which first gain a footing on the rocks, and of these were found on the island three or four species of *Placodium*, a half dozen or more rock *Lecanoras* as well as a larger number of *Biatoras*, *Lecideas* and *Buellias*. Of the foliaceous lichens the *Umbilicarias* are most characteristically rock pioneers; but these were very rare on the island, which did not furnish the high bluffs that they seek especially. As soon as rock decay has begun, the less strictly crustaceous species begin to appear. Of these *Pannaria microphylla* (Sw.) Delis was especially noticed sometimes growing on quite firm rock, but more frequently on rotten rock or a residual product of rock decay still *in situ* and protected by the lichen though sometimes several inches deep. Next come the typically foliaceous and fruticulose species as the *Peltigeras* and *Cladonias*. Finally enough soil is established so that smaller Spermaphytes and finally trees and shrubs become established, these larger ones in turn furnishing substrata for epiphytic lichens. At the present time, trees grow at one end of the ridge of highest land extending across the island while the other end is bare of trees and soil to a large extent and yet supports many strictly lithophytic lichens. At the shore line one finds amphibious *Endocarpons* and a *Collema* while typically xerophytic species cover the remainder of the island. The analysis could be extended to include a statement of different sorts of woody substrata which result in giving diversity of lichens growing on wood and, indeed, to give a detailed account of substrata including that of each one of the 88 species and varieties listed from the island. But this would lead to more detail than can be undertaken here, and for more minute account I have been compelled to select very small islands, though not offering so much diversity as to substrata, and have even then confined the analysis to the lithophytic and a few epigean species.

For this study of islands three were selected in the Snowbank lake area, and the lithophytic species were carefully noted on two of them and on the other also the decrease in number due to the establishment of an arboreal flora. It is to be regretted that the study could not have been extended to more islands and to include epiphytic and epigean species as well as lithophytic. Island number one is situated in Sucker lake, 30 feet from the shore, in the N. W. ¼ of S. W ¼ of S. E. ¼ of Sec. 1, T. 64 N., R. 9 W. The size of the island is about 70 x 75 feet. The surface is rocky with soil in a few places formed *in situ* or washed in from the lake, so that *Cladonias* were well established. About twenty shrubs were growing on the island and two rather small pines. The species noted in a short time are as follows:

1. **Cladonia rangiferina** (L.) Hoffm.
2. **Cladonia rangiferina** (L.) Hoffm. var. **sylvatica** L.
3. **Cladonia rangiferina** (L.) Hoffm. var. **alpestris** L.
4. **Cladonia pyxidata** (L.) Fr.
5. **Cladonia gracilis** (L.) Fr.
6. **Cladonia uncialis** (L.) Fr.
7. **Stereocaulon paschale** (L.) Fr.
8. **Umbilicaria muhlenbergii** (Ach.) Tuck.
9. **Endocarpon fluviatile** DC.
10. **Parmelia conspersa** (Ehrh.) Ach.
11. **Parmelia saxatilis** (L.) Fr.
12. **Parmelia caperata** (L.) Ach.
13. **Physcia** sp.
14. **Physcia stellaris** (L.) Tuck.
15. **Physcia speciosa** (Wulf., Ach.) Nyl.
16. **Physcia obscura** (Ehrh.) Nyl.
17. **Ephebe solida** Born.
18. **Pannaria microphylla** (Sw.) Delis.

19. **Urceolaria scruposa** (L.) NYL.
20. **Placodium vitellinum** (EHRH.) NAEG. and HEPP.
21. **Lecanora rubina** (VILL.) ACH.
22. **Lecanora cinerea** (L.) SOMMERF.
23. **Buellia petræa** (FLOT., KOERB.) TUCK.

Island number two is in Snowbank lake, 50 feet from the shore, in the N. W. ¼ N. E. ¼ of Sec. 29, T. 64 N., R. 8 W. near the outlet of the lake. The size of the island is about 80 x 100 feet, and it is thickly covered with trees and shrubs except in a few spots where *Cladonia rangiferina* (L.) Hoffm. persists. The species listed below for this island are excepting the *Cladonia*, confined to a circle of rock extending around the island and up from the water three inches to one foot. The species are as follows:

1. **Cladonia rangiferina** (L.) HOFFM.
2. **Endocarpon fluviatile** DC.
3. **Parmelia conspersa** (EHRH.) ACH.
4. **Parmelia caperata** (L.) ACH.
5. **Physcia obscura** (EHRH.) NYL.
6. **Leptogium lacerum** (SW.) FR.
7. **Placodium aurantiacum** (LIGHT.) NAEG. and HEPP.
8. **Lecanora subfusca** (L.) ACH.
9. **Lecanora cinerea** (L.) SOMMERF.

Island number three is in Disappointment lake, about 200 feet from the shore, in the N. E. ¼ of the S. E. ¼ of S. E. ¼ of Sec. 33, T. 64 N., R. 8 W. The size is 50 x 75 feet. The surface is rocky, with a few small shrubs growing in crevices, and is literally covered with rock lichens, and a few *Cladonias* and *Stercocaulons* growing along crevices and beginning to spread in one or two places. The following species were easily detected.

1. **Cladonia rangiferina** (L.) HOFFM.
2. **Cladonia rangiferina** (L.) HOFFM. var. **sylvatica** L.
3. **Cladonia pyxidata** (L.) FR.
4. **Cladonia uncialis** (L.) FR.
5. **Cladonia furcata** (HUDS.) FR.

6. **Stereocaulon paschale** (L.) FR.
7. **Umbilicaria muhlenbergii** (ACH.) TUCK.
8. **Umbilicaria pustulata** (L.) HOFFM.
9. **Endocarpon fluviatile** DC.
10. **Parmelia conspersa** (EHRH.) ACH.
11. **Parmelia saxatilis** (L.) FR.
12. **Parmelia caperata** (L.) ACH.
13. **Physcia** sp.
14. **Physcia stellaris** (L.) TUCK.
15. **Physcia cæsia** (HOFFM.) NYL.
16. **Leptogium lacerum** (SW.) FR.
17. **Ephebe pubescens** FR.
18. **Ephebe solida** BORN.
19. **Pannaria microphylla** (SW.) DELIS.
20. **Urceolaria scruposa** (L.) NYL.
21. **Placodium vitellinum** (EHRH) NAEG. and HEPP.
22. **Rinodina oreina** (ACH.) MASS.
23. **Lecanora rubina** (VILL.) ACH.
24. **Lecanora cinerea** (L.) SOMMERF.
25. **Buellia petræa** (FLOT., KOERB.) TUCK.

Comparing the lichens easily detected on islands numbers one and three—those which give character to the flora—whatever rare species may have escaped notice, we find that, of a total of 23 species and varieties on the first and 25 on the second, 19 are common to both islands, separated by several miles. The lists as a whole show a large number of foliaceous and fruticulose species; and we evidently have not the primitive post-pleistocene lichen population of these rocky islands, which indeed must have disappeared centuries ago. It is the more remarkable that practically the same species have succeeded in replacing a former flora on the two islands. I regret that time was wanting for the study of more of these islands, and especially of some farther from the shore line. The growth of larger forms of vegetation is probably beginning to effect a decrease in lichen species on island number one for otherwise, being larger, it should have furnished more species than number three rather than a smaller number. But it was only on number two that we found the unmistakable evidence of the effects of the arboreal vegetation in exterminating the lichens. Here too the species existing are all but two the same as those found on one or both of the other islands, but the number is reduced to little more than one-third as many as occur on either of them.

The succession of species is as apparent upon trees as upon rocks and is constantly in evidence in this largely undisturbed region where trees of various ages grow side by side. Some of the crustaceous lichens, of such genera as *Pyrenula*, *Arthonia* and *Graphis*, were usually found on young trees with smooth bark. As the substratum becomes more rugged with the increasing age of the tree, these are gradually replaced by foliaceous and fruticulose species as *Ramalinas*, *Usneas*, *Parmelias*, etc. Finally as the trees die certain species of *Calicium* *Cladonia*,*Peltigera*, *Parmelia*, etc., become the dominant types. It is not possible, nor is it necessary here, to give a detailed account of relation between each epiphytic lichen and its host, but a few of the most apparent relationships are in order. *Acer spicatum* Lam. supports *Arthonia dispersa* (Schrad.) Nyl. over the whole area. *Populus tremuloides* Michx. and *P. balsamifera* L. bear *Pyrenula leucoplaca* (Wallr.) Kbr. commonly. Some conifers, as *Pinus resinosus* Ait., *P. strobus* L., *Thuja occidentalis* L., serve for substrata for those species of the genus *Calicium* which grow on living trees. The most luxuriant growths of *Usnea* were found on *Picea mariana* (Mill.) and *Abies balsamea* (L.) Mill. *Graphis scripta* (L) Ach. var. *recta* (Humb.) Nyl. was almost wholly confined to *Betula lutea* Michx. and this same tree also supports *Sagedia oxyspora* (Nyl.) Tuck and two or three *Pyrenulas*.

A close analysis of the distribution of species within the area studied reveals much of interest even though it is a rather a restricted region. Of the 258 species and varieties listed, 96 were found only in one place, 32 in two, 31 in three, and the remaining 99 were collected along lake Superior and also inland, in four or more localities and are known to be generally distributed over the whole of the two counties. Also of those found in in two or three localities, 34 species were collected at some point along lake Superior and also beyond the ridge of high land formed by the Mesabi range and the Misquah hills and are doubtless quite generally distributed over the territory surveyed. Of these found in two or three places, 13 more were found along the lake and inland, but none beyond the divide mentioned above. These are doubtless generally distributed between this highest land and lake Superior, and of course may occur northwest of this high area as well.

Of course the 133 or more species most generally distributed over the area largely determined the character of its flora and are interesting in studying the relation of the flora of the region to that of others. But for the study of distribution within the area, as influenced by natural conditions, the chief interest centers around the 96 species found in one place only and those found in two or three areas and yet not generally distributed over the whole region. I give below a list stating the whole number collected in each principal collecting ground and also the number found at each one and not elsewhere. It will readily be seen that the last datum for each locality simply bears a close relative proportion to the first, or in other words, that no one area shows a large relative proportion of the rare species. Of course the data as to occurrence of these rare lichens can not be relied on fully; but about two-thirds of them are species of size large enough to be easy of detection, and while these may occur in other places, they are surely not common in the area. The table of species is as follows:

Grand Portage island,	total	collected,	88,	not	found	elsewhere,	15
Grand Portage,	"	"	59,	"	"	"	12
South Fowl lake,	"	"	14,	"	"	"	1
Rose lake,	"	"	20,	"	"	"	3
Gunflint,	"	"	118,	"	"	"	12
Misquah hills,	"	"	115,	"	"	"	11
Tofte,	"	"	85,	"	"	"	8
Beaver Bay,	"	"	82,	"	"	"	13
Palisades,	"	"	33,	"	"	"	1
Two Harbors,	"	"	14,	"	"	"	2
Ely,	"	"	41,	"	"	"	3
Snowbank lake area,	"	"	121,	"	"	"	15

The rather high per cent. of forms collected at Grand Portage only is due to the fact that the attempt was made to collect here especially species not found on the island. At an average about one-eighth of the species collected in each locality were not found elsewere. As stated above, two-thirds of these are conspicuous forms. The remaining one-third are some of the less conspicuous *Biatoras*, *Lecideas*, *Buellias*, *Graphises*, *Pyrenulas*, etc., which are not easily found.

When we consider the limited size of the area studied, the restriction of certain of the rarer species to certain parts of it rather than to others is worthy of careful study. The area lies on two sides of a divide extending approximately east and west and formed of the Mesabi range and the Misquah hills. The alpine or sub-alpine species not generally distributed over the area are mostly confined to the portion lying between the divide and lake Superior and to the Misquah hills on the divide, and also those found along the lake are for the most part found toward the northeastern portion of the territory traversed. The rarer temperate region species on the other hand are most numerous to the north and west of the divide, or toward the south of the portion between the lake and the divide. All of the data given above as to distribution within the area studied are based upon carefully prepared lists showing the distribution of each species. They can not all be reproduced, but parts of them must be. First of all, the facts concerning the species found only in one place can only be properly presented for consideration by the somewhat laborious table below, giving the various localities and species for each.

GRAND PORTAGE ISLAND.

Usnea cavernosa TUCK., N.

Physcia hispida (SCHREB.) FR., N.

Solorina saccata (L.) ACH., N.

Lecanora calcarea (L.) SOMMERF. var. **contorta** FR., T.

Cladonia gracilis (L.) NYL. var. **symphycarpia** TUCK., T.

Cladonia squamosa HOFFM. var. **phyllocoma** RABENH., T.

Cladonia deformis (L.) HOFFM., N.

Bæomyces byssoides (L.) SCHAER., N.

Biatora turgida (FR.) NYL., T.

Lecidea spirea ACH., N.

Endocarpon miniatum (L.) SCHAER., T.

Lecidea crustulata ACH., N.

Lecidea enteroleuca FR. var. **achrista** SOMMERF., T.

Staurothele drummondii Tuck., T.

Pyrenula cinerella (Flot.) Tuck., T.

Grand Portage.

Parmelia perforata (Jacq.) Ach. var. hypotropa Nyl., T.

Physcia adglutinata (Floerk.) Nyl., T.

Umbilicaria hyperborea Hoffm., N.

Nephroma lævigatum Ach. var. parile Nyl., N.

Placodium murorum (Hoffm.) DC. var. miniatum Tuck., T.

Lecanora muralis (Schreb.) Schaer var. diffracta Fr., T.

Biatora leucophæa Floerk. var. griseoatra Koerb., N.

Biatora lucida (Ach.) Fr., N.

Lecidea lapicida Fr. var. oxydata Fr., N.

Thelocarpon prasinellum Nyl., T.

Verrucaria nigrescens Pers., T.

Pyrenula cinerella (Flot.) Tuck. var. quadriloculata var. nov. (?).

South Fowl lake.

Alectoria sæpincola (Ehrh.) Ach., N.

Rose lake.

Heterothecium sanguinarium (L.) Flot. var. affine Tuck., N.

Opegrapha varia (Pers.) Fr. var. notha Ach., T.

Usnea barbata (L.) Fr. var. dasyopoga Fr., T.

Gunflint.

Physcia cæsia (Hoffm.) Nyl., T.

Pannaria nigra (Huds.) Nyl., T.

Placodium cinnabarrinum (Ach.) Anz., T.

Lecanora pallida (Schreb.) Schaer., T.

Lecanora hageni Ach., T.

Cladonia symphycarpa Fr. var. epiphylla (Ach.). Nyl., T.

Cladonia fimbriata (L.) Fr., T.

Cladonia gracilis (L.) Nyl. var. cervicornis Floerk., T.

Biatora glauconigrans Tuck., T.

Lecidea acclinis FLOT., T.

Buellia petræa (FLOT., KOERB.) TUCK. var. grandis FLOERK., N.

Arthonia patellulata NYL., T.

MISQUAH HILLS.

Parmelia centrifuga (L.) ACH., N.

Collema flaccidum ACH., T.

Placodium murorum (HOFFM.) DC., T.

Lecanora subfusca (L.) ACH. var. hypnorum SCHAER., T.

Pertusaria glomerata (ACH.) SCHAER., N.

Biatora oxyspora (TUL.) NYL., T.

Biatora schweinitzii FR., T.

Lecidea lapicida FR., N.

Lecidea albocærulescens WULF.) SCHAER., N.

Lecidea platycarpa ACH., N.

Graphis scripta (L.) ACH. var. limitata ACH., T.

TOFTE.

Parmelia perforata (JACQ.) ACH., T.

Sticta limbata (SM.) ACH., N.

Leptogium myochroum (EHRH.) SCHAER., T.

Lecanora elatina ACH., T.

Stereocaulon coralloides FR., N.

Cladonia cæspiticia (PERS.) FL., T.

Cladonia digitata (L.) HOFFM., N.

Calicium chrysocephalum (TURN.) ACH. var. filare ACH., T.

BEAVER BAY.

Ramalina calicaris (L.) FR. var. fastigiata FR., T.

Ramalina pollinarella NYL., T.

Placodium cerinum (HEDW.) NAEG. and HEPP. var. pyracea NYL., T.

Placodium vitellinum (EHRH.) NAEG. and HEPP., T.

Lecanora calcarea (L.) SOMMERF., T.

Cladonia mitrula TUCK., T.
Cladonia delicata (EHRH.) FL., T.
Cladonia decorticata FLOERK., T.
Biatora coarctata (SM., NYL.) TUCK., T.
Biatora myriocarpoides (NYL.) TUCK., T.
Biatora nægelii HEPP., T.
Buellia myriocarpa (DC.) MUDD., T.
Sagedia oxyspora (NYL.) TUCK., T.

PALISADES.

Cetraria islandica (L.) ACH., N.

TWO HARBORS.

Physcia aquila (ACH.) NYL., T.
Buellia dialyta (NYL.) TUCK., T.

ELY.

Lecanora tartarea (L.) ACH., T.
Buellia myriocarpa (DC.) MUDD. var. **polyspora** WILLEY., T.
Calicium trichiale (ACH.) var. **stemoneum** NYL. T.

SNOWBANK LAKE AREA.

Ramalina calicaris (L.) FR. var. **canaliculata** FR., T.
Ramalina pusilla (PREV.) TUCK., N.
Parmelia tiliacea(HOFFM.)FLOERK. var. **sublævigata** NYL.,T.
Collema pycnocarpum NYL., T.
Leptogium lacerum (SW.) FR., T.
Leptogium lacerum (SW.) FR. var. **pulvinatum** MOUG. and NESTL., T.
Rinodina sophodes (ACH.) NYL. var. **confragosa** NYL., T.
Gyalecta fagicola (HEPP.) TUCK., T.
Biatora sphæroides (DICKS.) TUCK., T.
Biatora fuscorubella (HOFFM.) TUCK., T.
Biatora muscorum (SW.) TUCK., T.
Lecidea cyrtidia TUCK., T.
Buellia parmeliarum (SOMMERF.) TUCK., T.

Coniocybe pallida (PERS.) FR., T.

Verrucaria epigæa (PERS.) ACH., T.

In the above table all of the arctic and subarctic species are marked (N.) and the species common in temperate regions at low elevations (T.). Beginning then with the areas between the divide formed by the Mesabi range and the Misquah hills and lake Superior and toward the north of this region, of a total of 15 species found only on Grand Portage island, seven or one less than half are characteristic of northern regions. Of 12 confined to Grand Portage, five or about 42 per cent. are northern species. A single one collected only at South Fowl lake and one of three at Rose lake are also northern. Of the 12 found only at Gunflint and the 15 found only in the Snowbank lake area, only one strictly northern species is restricted to each place, while for Ely of the three restricted species not one is northern. Consideration of the figures will show that for the five localities along the international boundary there is a decrease in proportion of rare arctic or alpine species in passing westward along the boundary. Again passing southward from Grand Portage we found three northern of a total eight species confined to Tofte, and the one species taken only at the Palisades is northern. The thirteen species found only at Beaver Bay and the two collected only at Two Harbors are all distinctly temperate region plants. Thus it appears that the northern species give way to those more characteristic of temperate regions in passing southward even along the shores of lake Superior where the cold lake winds have greatest influence upon the flora. An elevation of more than 1,000 feet was reached at Beaver Bay without finding northern species while at Grand Portage about 150 miles northeast they descend to the lake level. At Tofte a short distance northeast of Beaver Bay we reached an elevation of 1,529 feet on Carlton peak in the Sawteeth mountains and found three northern species. Only one of the three species was taken at the summit of Carlton peak, but this is because the top of the peak is burned over. The other two species were collected at a considerable distance above the base of the peak and are doubtless to be found on unburned portions of the Sawteeth mountains near by.

In the discussion of the table thus far the Misquah hills area has not been considered. As stated elsewhere this area is the highest portion of the State, reaching 2,230 feet, and the region gave five arctic or subarctic species of a total of eleven collected only here. The influence of elevation becomes apparent when we compare the Misquah hills area with the Gunflint region as to number of northern species. The latter locality lies 20 miles north of the former and about 400 feet lower, only a small portion of it near the Paulson mines reaching 2,000 feet. The Misquah hill area which is a more extended region of higher elevation furnished the goodly proportion of northern forms noted above while the Gunflint area gave only one such species in a total of twelve found only in the area.

Of all the species found only in one place 25, or more than one-fourth, are arctic or subartic and 71, or approximately three-fourths are plants characteristic of temperate regions. Without entering into the yet more complicated analysis which a consideration of these rare temperate region plants would involve, a mere inspection of the table will show in a general way that their distribution is just the reverse of that of the northern species, or that they are especially characteristic of that small portion of the region studied which lies to the north of the divide and of the southern portion of the region lying between the divide and lake Superior. Of course it could also be shown that they are more especially characteristic of the lower elevations.

Of the 63 species collected only in two or three places, only a half dozen are arctic or subarctic species, and it would have been useless to give the whole 63 in tabular form as no safe data could be obtained from so small a proportion of northern species. However, the 6 northern species are as follows:

Ramalina pusilla (PREV.) TUCK. var. **geniculata** TUCK.

Parmelia encausta (SM.) NYL.

Sticta scorbiculata (SCOP.) ACH.

Lecanora frustulosa (DICKS.) MASS.

Lecanora sordida (PERS.) TH. FR.

Buellia geographica (PERS.) TUCK.

In order that we may have all of the northern species before us for a final consideration, I shall give a list of those generally distributed as follows:

Lecidea lactea FL.

Buellia petræa (Flot., Koerb.) Tuck.

Buellia petræa (Flot., Koerb.) Tuck. var. montagnæi Tuck.

Umbilicaria vellea (L.) Nyl.

Nephroma tomentosum (Hoffm.) Neck.

Pannaria epidiota Th. Fr.

Stereocaulon paschale (L.) Fr.

Cladonia amaurocræa (Fl.) Schaer.

Bæomyces æruginosus (Scop.) DC.

Heterothecium sanguinarium (L.) Flot.

Taking into account the above table, we find that of a total of 99 species and varieties generally distributed over the area studied only 10, or one-ninth, are arctic or subarctic, and considering both of the last two tables we see that of 162 species and varieties more or less widely distributed 16, or nearly one-ninth, are arctic or subarctic. It has been stated that about one-fourth of the species found only in one place are such northern forms. Thus we find that the more general the distribution of a series of plants in the area the smaller the per cent. of northern species, and conversely the larger the per cent. of temperate region species. In other words the prevailing species are those characteristic of temperate regions, and as a whole the rarer ones are the more northern floral elements. Since the introduction of new species is commonly a more rapid process than the complete extermination of others in a given region, the existing conditions above stated seem to prove, as one would naturally suppose, that the present lichen flora of the region is in general of temperate region elements and that the more northern elements of the flora are the persisting for most part in a few favorable spots. This supposition also explains the existence of the northern species in isolated regions further south as I have done for Taylors Falls. Professor Conway MacMillan has considered the spermaphytic flora of this region as a south-bound one,* or at least that of the portion between the divide and lake Superior. My observations here and at Taylors Falls do not indicate that this is generally true of the lichens. However, because of somewhat milder temperature, lower elevation and perhaps more early retreat of the ice sheet in the western half of the State, the temperate region lichens have no doubt driven or followed the northern species farther north there and doubtless very few of the latter elements now exist in western Minnesota south of Lake of the Woods, or indeed anywhere in the western half of the state. Since gaining possession of the northwestern part of the state these temperate region lichens have doubtless been moving southward over the Mesabi range to meet similar floral elements of a generally northward bound lichen flora. The western half of the state remains to be explored for lichens, but the above statement as to the character of the flora, based on observations recorded in this paper for localities north of the Mesabi range and some knowledge of the general character of the region, I regard as sufficiently secure.

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*MacMillan C. Observations on the distribution of plants along the shore at Lake of the Woods. Minn. Bot. Stud. 1 : 954. 1897.

Like the Taylors Falls region this one of course at one time contained only arctic species, and the present more numerous species characteristic of temperate regions have gained the ascendency in quite recent time. However, the problems involved in the struggle betwen the contending floral elements do not force themselves upon the observer so strongly in this larger area and must be dismissed with a much briefer statement. As in the Taylors Falls region the persisting northern species are largely lithophytic. This is shown in the following exhibit of substrata for the 42 species :

Arctic or subarctic lichens confined to rocks	25
“ “ “ “ “ “ trees	8
“ “ “ “ “ “ earth	4
“ “ “ “ “ “ dead wood	2
“ “ “ “ “ “ dead wood and trees	1
“ “ “ “ “ “ earth and rocks	1
“ “ “ “ “ “ trees “ “	1

The greater persistence of the lithophytic species is doubtless due in part at least to the greater stability of the rock surfaces and also probably in part to the fact that the arctic and subarctic species became more thoroughly established on the rocks, which were present for them to attack immediately at the close of the Pleistocene before the advent of large trees and temperate-region lichens.

Thus far I have given a detailed account of habitat for the northern species only. Of the whole 258 species and varieties listed in this paper, so far as observation showed, 83 are epiphytic, 80 lithophytic and 29 may occur on either trees or rocks. Another 29 are epigean, 22 were found only on dead wood, six are lithophytic or epigean, three are found on earth and dead wood, three are parasitic on other lichens and two were found on living and dead wood. The above analysis of substrata is somewhat different from that used in the second paper of this series for comparison of substrata at Minneapolis and at Fayette, Iowa; but when reduced to that form shows that the percentage of lichens growing on rocks is somewhat higher than that for the two areas farther south, while the percentage of those growing on wood is considerably lower. The larger proportion of rock lichens in the Superior region is due to at least three things. First, the more extensive exposure of rock surfaces, though this is offset in part at least by the existence of three distinct kinds of rock in the Minneapolis region, viz.: the igneous or metamorphic boulders, the limestone outcrops and the Saint Peter sandstone. Second, the rock surfaces become warmer, each day in the warm portion of the year, than the trees, because of rapid absorption of heat; and this doubtless favors lichen development on rocks in this northern region. Third, general moisture of much of the surface due to the fact that the rocks are comparatively impervious to water, so that much of it collects in lakes and swamps, favors good development of rock lichens as compared with the region about Minneapolis. At Minneapolis unshaded rocks bear very few lichens, but in the Superior region rocks are well populated with them at all elevations and in all sorts of environment at or above the water line, except where killed by fire.

The total number of genera for the region is 39, while the number for Minneapolis and Taylors Falls, so far as is known, is 34. The whole number for Illinois, as given by Wolf and Hall* is 40 and for Iowa as recorded by the writer in two papers† is 38. This total number of genera for the Superior region is seen by the comparisons with both larger and smaller areas further south to be rather large for a somewhat limited northern area, but a locality where northern and more temperate floral elements meet seems to compensate fully at least for difference in latitude.

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* Wolf, John and Hall, Elihu. A List of the Mosses, Liverworts and Lichens of Illinois. Bull. Ills. State Lab. Nat. Hist. 2: 18–34. June, 1878.

† Fink B. Lichens of Iowa. Bull. Lab. of Nat. Hist., State Univ. of Iowa 3: 70–88. Mr. 1895, and Notes concerning Iowa Lichens, Proc. Iowa Acad. Sci. 5: 174–187. 1897.

The genera giving most of the species new to the state are the following, given in tabular form with the total number of species collected in each genus and the number new to the state.

Ramalina,	collected	6,	new to the State	4.
Cetaria,	"	7,	" " "	5.
Sticta,	"	5,	" " "	3.
Nephroma,	"	4,	" " "	3.
Solorina,	"	1,	" " "	1.
Lecanora,	"	25,	" " "	15.
Gyalecta,	"	1,	" " "	1.
Bæomyces,	"	2,	" " "	2.
Biatora,	"	23,	" " "	16.
Heterothecium,	"	2,	" " "	2.
Lecidea,	"	12,	" " "	9.
Calicium,	"	9,	" " "	9.
Coniocybe,	"	1,	" " "	1.
Sagedia,	"	1,	" " "	1.

Of these genera *Solorina*, *Bæomyces*, *Heterothecium*, *Calicium*, *Coniocybe*, and *Sagedia* are new to the State. An inspection of the above list shows that the genera are for the most part those furnishing large numbers of arctic and subarctic species, or species hitherto supposed to be confined to New England. The genera *Stereocaulon* and *Umbilicaria* are equally characteristic of northern and eastern areas, but two-thirds of the species of these genera here recorded were listed for Minnesota in the first paper of this series.

By comparing the present list of species and varieties with those recorded for Minneapolis and Taylors Falls we find that that there are 152 lichens growing in the territory considered in this paper and not found in either of the two areas named above, while there are 33 found in them and not in the northeastern Minnesota area under consideration. This leaves only 73 lichens known to be common to central and northeastern Minnesota. In the comparison between Minneapolis and certain localities in northeastern Iowa it was shown that no species have been found at the former place and not in the latter region, though Minneapolis is 150 miles north of Fayette, the principal Iowa area considered. In passing about 200 miles north from

Minneapolis, on the other hand, we find a lichen flora, about three-fifths of whose species and varieties are not found at Minneapolis and about half of which are new to the state. The region of rapid transition in lichen species lies between the Minneapolis and Superior areas and has only been touched in the study of its rock lichens at Taylors Falls. As stated in the third paper of this series, this region is one of special interest for tracing the distribution of species. The cause of the great difference in lichen flora between Minneapolis and the Superior region is scarcely due in any great measure to difference in latitude since an almost equal difference in latitude to the south of Minneapolis caused no appreciable difference in the flora. Also, I have shown in this paper that in three localities lying in the northern part of the region studied in the paper, viz.: Snowbank lake, Ely and Gunflint, very few typically northern species are found. These regions at the north of the area are more closely related to the Minneapolis region as to lichen flora than others 50 or 75 miles further south. The difference in lichen flora between central and northeastern Minnesota seems then to be due chiefly to three factors. The first is difference in substrata. The limestones of the Minneapolis regions, as well as the sandstone, are almost entirely wanting in northeastern Minnesota, being replaced by an abundance of igneous or metamorphic rocks. The conifers, which abound in the northern part of the State, and which serve for substrata for quite a number of species not found southward, form the other chief difference as to substrata. Location in the valley of lake Superior, where the region is shut off from warmer regions west and north as well as south, is another factor that has caused much of the difference in flora. It has been shown that the number of arctic and subarctic species for a given elevation decreases in passing southwestward along the lake. This I suppose to be due not so much to difference in latitude as to the fact that in the northeastern part of the region studied along the lake the winds coming from the broader expanse of water, on this largest American fresh water area, are rendered cooler than farther down where the lake is not so wide. That the cold winds are a factor is demonstrated by the occurrence of a large proportion of northern species at the Grand Portage area, and especially on the island which rises little more than 100 feet above the lake, while such inland areas as Gunflint and Snowbank lake, which are somewhat farther north, are almost entirely devoid of such species. A third factor is increase in elevation. The influence of elevation has been discussed in considering the Misquah hills and the Sawteeth mountains. Concerning cold lake winds and elevation, it is significant that of the 25 arctic and subarctic species found only in one place, 16 are found at stations along the lake, and that of the remaining 9, 5 are found in the Misquah hills, the region of highest elevation. Thus all but 4 of these 25 species were collected where one or both of these factors have most influence.

It is not possible to state just which ones of the many species found either in central or in northeastern Minnesota and not in the other area would be of most interest in studying the territory lying between the two regions. Of course, the foliaceous and fruticulose species are most easily found, and some of these are most likely to be collected. I may add that interest would centre chiefly about species which are common and give character to the flora in one of the two areas and are not found in the other. Not attempting to select from some 150 species collected in the Superior area and not farther south in the state, I will name, from 27 or 28 species found to the south and not to the north of the unexplored area, *Theloschistes concolor* (Dicks.) Tuck. and *Physcia granulifera* (Ach.) Tuck. as two species that any botanist can soon learn to distinguish in the field, which are common in the south half of Minnesota and not known farther north in the state, and whose distribution between Minneapolis and Two Harbors would be of special interest. Nearly all of the remainder of the 27 or 28 species are either infrequent or rare about Minneapolis, are confined to substrata not existing in northeastern Minnesota, or are so inconspicuous as to render their study in the field difficult.

As a fitting close to these observations on the distribution of lichens in different regions of the state I may give some notes concerning certain species for most part characteristic of more southern portions and found also in northeastern Minnesota. *Parmelia borreri* Turn. was not found fruited along the lake north of Beaver Bay. *Peltigera aphthosa* (L.) Hoffm. seeks high ground in the southern stations from which it is recorded and in the northwestern as well and is one of the species whose farther southern and western extent in the state would be especially worthy of study. *Parmelia tiliacea* (Hoffm.) Tuck. becomes somewhat common at the southwest and more so at the northwest portion of the territory studied. It is one of the southern intrusions which extend farther north at some distance from lake Superior. Trees common farther south in Minnesota were noted north of the Mesabi range as *Quercus macrocarpa* Michx. *Cratægus* sp. and *Fraxinus* sp. On *Fraxinus* was found *Coniocybe pallida* (Pers.) Fr. which is common in northeastern Iowa, and on the same host *Pyrenula leucophaca* (Wallr.) Kbr. also becomes common for the first time in this northern area. Other lichens in the list of those found only north of the Mesabi range or the Misquah hills could be selected for special treatment, and on the whole this portion of the Superior region shows a closer floral connection with central Minnesota than does the most southern point reached, viz., Two Harbors.

The list of 258 species and varieties is a large one for a rather limited area to yield, especially when it is stated that only about 300 lichens have been listed for Minnesota, including the present list. Yet the undisturbed portions of the region are more remarkable for richness in individuals than for large numbers of species. The Grand Portage area gave 132 species and varieties and the Snowbank lake area 121. These two areas are the ones best studied and are perhaps as thoroughly explored as the Minneapolis area, which gave 113 species and varieties. Both of the former two are like the latter small areas and the comparison seems to indicate that the lake Superior region is, area for area, only slightly richer in species than the Minneapolis region. Professor L. H. Bailey* found that the species of *Spermaphytes* and higher *Archegoniates* of the region are only about one-tenth as numerous at lake Vermilion as in similar areas six degrees farther south, and we should of course expect some decrease in lichen species rather than an increase in passing northward in the state. The reverse condition existing is largely due to diverse conditions within the region as to elevation and temperature and as to surface moisture, all of which factors have been duly considered. The Snowbank lake area studied is a larger one than the Grand Portage. About equal time was spent at the two places, and we did much more of the time-consuming quantity-collecting at Grand Portage. Yet fewer forms of lichens were collected about Snowbank lake. This seems to indicate that the lake shore is richer in lichen species than in interior areas of the territory studied.

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* Bailey, L. H., in Arthur, J. C. Report on botanical work in Minnesota in 1886. Geol. and Nat. Hist. Surv. of Minn., Bull. 3 : 8. 1 O., 1887.

It is well known that a large portion of the species of lichens of the interior of North America are those found also in regions bordering upon the Atlantic ocean along our eastern border. This was brought out by the writer in a previous paper,* but all the species recorded in that paper were temperate region lichens. It has remained for the present paper to record a large number of more northern lichens previously for the most part known only in arctic or subarctic regions, or descending from mountains farther south only along our Atlantic border.

Of the 258 species and varieties listed below 46 are new to the North American interior or to the interior of the United States, and of these six are new west and north of New England. In treating of distribution the expression "the interior of North America" means the area lying between the Appalachian system of mountains on the east and the Rocky Mountains on the west. A number of species noted as new to the interior have been reported from New York or Canada, and doubtless a few of them were previously found a short distance west of the Appalachian system of mountains.

LIST OF SPECIES AND VARIETIES.

1. **Ramalina calicaris** (L.) Fr. var. **fastigiata** Fr.

On trees, rare. Beaver Bay, July 13, 1897, no. 677.

2. **Ramalina calicaris** (L.) Fr. var. **canaliculata** Fr.

On trees, rare. Snowbank lake area, July 23, 1897, no. 895. Not previously reported from Minnesota.

3. **Ramalina calicaris** (L.) Fr. var. **farinacea** Schaer.

On rocks, common or frequent over whole area and rarely found on trees also. Grand Portage island, June 23, 1897, no. 106. Gunflint, June 30, 1897, no. 257. Misquah hills, July 3, 1897, no. 419, and July 7, 1897, no. 539. Tofte, July 10, 1897, no. 624. Palisades, July 15, 1897, no. 763. Snowbank lake area, July 24, 1897, no. 934.

All except no. 763 were lighter colored than other forms of the species. No. 106 occasionally and no. 763 quite commonly are irregularly branched and with dilated terminal soredia like *R. pollinaria* (ACH.) TUCK.

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* Fink, B. Lichens of Iowa. Bull. Lab. of Nat. Hist., State Univ. of Iowa. 3: 70–78. Mr., 1895.

4. **Ramalina pusilla** (PREV.) TUCK.

On trees, frequent. Grand Portage island, June 19, 1897, no. 34. Snowbank lake area, July 20, 1897, no. 844.

Not previously reported from Minnesota and new to the interior of North America.

5. **Ramalina pusilla** (PREV.) TUCK. var. **geniculata** TUCK.

On trees, infrequent or rare. Gunflint, July 2, 1897, no. 375. Beaver Bay, July 13, 1897, no. 675.

Not previously reported from Minnesota and new to the interior of the United States.

6. **Ramalina pollinarella** NYL.

On rocks, rare. Beaver Bay, July 13, 1897, no. 681.

Not previously reported from Minnesota and new to the interior of North America.

7. **Cetraria aurescens** TUCK.

On trees, rare. Tofte, July 10, 1897, no. 636. Snowbank lake area, July 21, 1897, no. 869.

Not previously reported from Minnesota and new to the interior of North America.

8. **Cetraria islandica** (L.) ACH.

On earth above the Palisades, rare, July 15, 1897, no. 765. Not previously reported from Minnesota.

9. **Cetraria ciliaris** (ACH.) TUCK.

On trees, abundant on Grand Portage island, elsewhere only rare or frequent. Grand Portage island, June 18, 1897, no. 10. Gunflint, July 2, 1897, nos. 387 and 396 at Misquah hills, July 3, 1897, no. 427. Snowbank lake area, July 22, 1897, no. 883, and July 26, 1897, no. 948. Ely, July 28, 1897, no. 1022.

10. **Cetraria lacunosa** ACH.

On trees, common. Top of bluff at south end of South Fowl lake, June 26, 1897, no 206. Gunflint, July 2, 1897, no. 401. Misquah hills, July 3, 1897, no. 442. Tofte (Carlton peak), July 10, 1897, no. 556. Beaver Bay, July 14, 1897, no. 733. Snowbank lake area, July 21, 1897, no. 946.

Not noted at Grand Portage where the last above was abundant, but seeming to replace it in part elsewhere, being common in the localities noted above.

11. **Cetraria juniperina** (L.) Ach. var. **pinastri** Ach.

On trees and old logs. Common at Grand Portage and Misquah hills, elsewhere infrequent or rare, sterile. Grand Portage island, June 18, 1897, no. 15. Gunflint, June 30, 1897, no. 261. Misquah hills, July 3, 1897, no. 411. Beaver Bay, July 13, 1897, no. 679. Snowbank lake area, July 21, 1897, no. 865. Ely, July 28, 1897, no. 1016.

Not previously reported from Minnesota and new to the interior of North America.

12. **Cetraria sæpincola** (Ehrh.) Ach.

On trees, rare. South Fowl lake, June 27, 1897, no. 201.

Not previously reported from Minnesota and new to the interior of North America.

13. **Evernia furfuracea** (L.) Mann.

On trees, rare, sterile. Gunflint, July 2, 1897, no. 397. Misquah hills, July 3, 1897, no. 434. Tofte (Carlton peak), July 10, 1897, no. 573.

Not previously reported from Minnesota.

14. **Evernia prunastri** (L.) Ach.

On trees, common. Only seen fertile once. Grand Portage island, June 22, 1897, no. 81. Gunflint, June 30, 1897, no. 267. Misquah hills, July 3, 1897, no. 428. Tofte (Carlton peak), July 10, 1897, no. 554. Tofte, July 10, 1897, no. 635. Beaver Bay, July 14, 1897, no. 717. Two Harbors, July 17, 1897, no. 789. Snowbank lake area, July 20, 1897, no. 841. Ely, July 28, 1897, no. 1002.

15. **Usnea barbata** (L.) Fr. var. **florida** Fr.

On trees, common or abundant but sterile. Grand Portage island, June 17, 1897, no. 8. Misquah hills, July 3, 1897, no. 420. Tofte (Carlton peak), July 10, 1897, nos. 557 and 607. Beaver Bay, July 14, 1897, no. 722. Snowbank lake area, July 14, 1897, No. 814.

The last has the minute and numerous fibrils of var. *hirta* Fr., but it is not sorediate; while the forms given below under that variety are sorediate, but the fibrils are seldom minute.

16. **Usnea barbata** (L.) Fr. var. **hirta** Fr.

On trees, common or abundant but sterile. Grand Portage island, June 16, 1897, no. 9. Gunflint, July 1, 1897, no. 356. Misquah hills, July 5, 1897, no. 477. Tofte (Carlton peak), July 10, 1897, nos. 562 and 569. Tofte, July 12, 1897, no.

649. Beaver Bay, July 13, 1897, no. 671. Snowbank lake area, July 19, 1897, nos. 806 and 851. Ely, July 28, 1897, no. 1001.

17. **Usnea barbata** (L.) FR. var. **ceratina** SCHAER.

On trees, common or abundant but sterile. Gunflint, June 30, 1897, no. 263. Misquah hills, July 3, 1897, no. 423. Tofte, (Carlton peak), July 10, 1897, no. 558. Beaver Bay, July 13, 1897, nos. 665 and 672. Snowbank lake area, July 19, 1897, no. 807. Ely, July 28, 1897, no. 993.

Not previously reported from Minnesota.

18. **Usnea barbata** (L.) FR. var. **dasypoga** FR.

On trees, common. Rose lake, June 28, 1897, no. 213.

19. **Usnea barbata** (L. FR. var. **plicata** FR.

On trees, common. Snowbank lake area, July 19, 1897, no. 805. Ely, July 28, 1897, no. 994.

20. **Usnea trichodea** ACH.

On trees, common. Grand Portage island, June 23, 1897, no. 157. English portage, June 26, 1897, no. 190. Rose lake, June 28, 1897, no. 212. Gunflint, July 2, 1897, no. 381. Misquah Hills, July 3, 1897, no. 432, and July 5, 1897, no. 544. Tofte (Carlton peak), July 10, 1897, no. 547. Tofte, July 12, 1897, no. 659. Beaver Bay, July 13, 1897, no. 667. Two Harbors, July 17, 1897, no. 793.

Not previously reported from Minnesota.

21. **Usnea longissima** ACH.

On trees, common along lake Superior and possibly in Misquah hills. Sterile. Grand Portage island, June 18, 1897, no. 19. Misquah hills, July 3, 1897, no. 422. Tofte, July 12, 1897, no. 649. Beaver Bay, July 13, 1897, no. 649a. Two Harbors, July 17, 1897, no. 787. Snowbank lake area, July 20, 1897, no. 850.

Specimens were collected at Grand Portage island five feet long. The plant breaks with its own weight and hangs abundantly over branches unattached.

Not previously reported from Minnesota.

22. **Usnea cavernosa** TUCK.

On trees, common. Grand Portage island, June 17, 1897, nos. 6 and 18.

23. **Alectoria jubata** (L.) TUCK.

On trees abundant on Grand Portage island, infrequent to common elsewhere. Sterile. Grand Portage island, June 18, 1897, no. 17. Gunflint, July 1, 1897, no. 354. Tofte, July 12, 1897, no. 658. Beaver Bay, July 13, 1897, no. 680. Snowbank lake area, July 20, 1897, no. 837. Ely, July 28, 1897, no. 996.

24. **Alectoria jubata** (L.) TUCK. var. **chalybeiformis** ACH.

On trees and old wood, frequent or common throughout. Sterile. High bluff at south end of South Fowl lake, June 26, 1897, no. 194. Gunflint, June 30, 1897, no. 258, and July 1, 1897, no. 316. Misquah hills, July 5, 1897, no. 514. Beaver Bay, July 15, 1897, no. 786. Snowbank lake area, July 19, 1897, no. 815, and July 20, 1897, no. 842. Ely, July 28, 1897, no. 998.

25. **Alectoria jubata** (L.) TUCK. var. **implexa** FR.

On trees, infrequent. Sterile. Misquah hills, July 3, 1897, no. 421. Beaver Bay, July 14, 1897, no. 731.

Not previously reported from Minnesota.

26. **Theloschistes polycarpus** (EHRH.) TUCK.

On trees, infrequent or rare west of Gunflint, elsewhere frequent or common. Grand Portage island, June 18, 1897, no. 20. Gunflint, July 2, 1897, no. 393. Misquah hills, July 5, 1897, nos. 452 and 487. Beaver Bay, July 13, 1897, nos. 678 and 686. Ely, July 28, 1897, no. 985.

27. **Theloschistes lychneus** (NYL.) TUCK.

On rocks, rare. Grand Portage island, June 23, 1897, no. 147. Snowbank lake area, July 19, 1897, no. 830.

28. **Parmelia perlata** (L.) ACH.

On rocks and rarely on trees, rare to infrequent except at Gunflint, where the species seemed to be common. Sterile. Grand Portage, June 24, 1897, no. 169. Portage between South Fowl lake and Pigeon river, June 26, 1897, no. 205. Gunflint, June 7, 1897, no. 368. Misquah hills, July 5, 1897, no. 543. Beaver Bay, July 14, 1897, no. 725. Snowbank lake area, July 24, 1897, no. 925.

29. **Parmelia perforata** (JACQ.) ACH.

On trees, common. Sterile. Tofte (Carlton peak), July 10, 1897, no. 572.

A puzzling plant with sorediate margined lobes and otherwise resembling the last. However, the margins of the lobes are quite strongly ciliate, and the lower surface of the thallus interruptedly so; possibly might be referred to *P. perlata* (L.) ACH. var. *ciliata.* DC. Thallus rather thinner than my herbarium specimens of *P. perforata.*

30. **Parmelia perforata** (JACQ.) ACH. var. **hypotropa** NYL.
On rocks, rare. Grand Portage, June 23, 1897, no. 116. Not previously reported from Minnesota.

31. **Parmelia crinita** ACH.
On rocks and once collected on trees, rare or infrequent. Sterile. Grand Portage, June 23, 1897, no. 114. Gunflint, July 1, 1897, nos. 361 and 362. Tofte, July 10, 1897, no. 627. The plant differs from my Iowa and Ohio specimens in that it is strongly ciliate on the upper surface of the thallus among the branchlets and granules.

32. **Parmelia tiliacea** (HOFFM.) FLOERK.
On trees, rare or infrequent. Gunflint, July 2, 1897, no. 407a. Tofte (Carlton peak), July 10, 1897, no. 620. Beaver Bay, July 14, 1897, no. 724a. Ely, July 28, 1897, no. 1018.

Really more frequent along boundary at west. Was frequently noted in Snowbank lake area and failure to get specimens was an oversight.

33. **Parmelia tiliacea** (HOFFM.) FLOERK. var. **sublævigata** NYL.
On trees, rare. Snowbank lake area, July 23, 1897, no. 896.

Not previously reported from Minnesota.

34. **Parmelia borreri** TURN. var. **rudecta** TUCK.
On rocks and trees, rare or infrequent, except common in the Snowbank lake area. All sterile except no. 744 on rocks. Grand Portage, June 24, 1897, no. 188. Gunflint, July 1, 1897, no. 369. Misquah hills, July 3, 1897, no. 431. Tofte (Carlton peak) July 10, 1897, no. 612. Palisades, July 15, 1897, nos. 744 and 762. Snowbank lake area, July 30, 1897, no. 839. Ely, July 28, 1897, no. 983.

35. **Parmelia saxatilis** (L.) FR.
On trees and rarely on rocks. Abundant or common and frequently fruited. Grand Portage island, June 17, 1897, no. 7, and June 21, 1897, no. 57. Misquah hills, July 3, 1897, no.

406. Beaver Bay, July 14, 1897, no. 741. Snowbank lake area, July 21, 1897, no. 873.

36. **Parmelia saxatilis** (L.) FR. var. **sulcata** NYL.

On trees, probably common. Grand Portage island, June 17, 1897, no. 7a. Gunflint, June 30, 1897, no. 240.

Not previously reported from Minnesota.

37. **Parmelia physodes** (L.) ACH.

On trees and rocks, common. Gunflint, July 1, 1897, no. 383. Snowbank lake area, July 2, 1897, no. 883.

Doubtless occurring over the whole region studied, but taken for *P. saxatilis* (L.) FR. modified by some peculiarity of substratum.

38. **Parmelia encausta** (SM.) NYL.

On trees, common. Grand Portage island, June 6, 1897, no. 143. Tofte (Carlton peak), July 10, 1897, no. 565.

Not previously reported from Minnesota and new to the interior of North America.

39. **Parmelia olivacea** (L.) ACH.

On trees, common. Grand Portage island, June 18, 1897, no. 11. Grand Portage, June 23, 1897, no. 100. Gunflint, June 30, 1897, no. 260, and July 2, 1897, no. 395. Tofte (Carlton peak), July 10, 1897, nos. 585 and 591. Beaver Bay, July 13, 1897, no. 712. Snowbank lake area, July 20, 1897, no. 848. Ely, July 28, 1897, no. 1004.

40. **Parmelia olivacea** (L.) ACH. var. **prolixa** ACH.

On rocks, common or frequent. High bluff at south end of South Fowl lake, June 26, 1897, no. 197. Gunflint, June 30, 1897, no. 290. Misquah hills, July 5, 1897, no. 491. Tofte (Carlton peak), July 10, 1897, no. 574. Beaver Bay, July 13, 1897, no. 703. Palisades, July 15, 1897, no. 742a. Snowbank lake area, July 20, 1897, no. 832.

Not previously reported from Minnesota and new to the interior of North America.

41. **Parmelia caperata** (L.) ACH.

On trees and rocks, common. Grand Portage island, June 23, 1897, no. 107. Gunflint, June 30, 1897, no. 254a. Misquah hills, July 3, 1897, no. 403. Tofte (Carlton peak), July 10, 1897, no 608. Beaver Bay, July 14, 1897, no. 728. Palisades, July 15, 1897, no. 768. Snowbank lake area, July 19, 1897, no. 804 and July 24, 1897, no. 916.

More commonly fruited than farther south and especially well fruited in the Snowbank lake area.

42. **Parmelia conspersa** (EHRH.) ACH.

On rocks, abundant or common. Grand Portage island, June 23, 1897, no. 103. Gunflint, June 30, 1897, no. 289. Misquah hills, July 5, 1897, no. 506. Tofte (Carlton peak), July 10, 1897, no. 621. Palisades, July 15, 1897, no. 755. Snowbank lake area, July 27, 1897, no. 967.

43. **Parmelia centrifuga** (L.) ACH.

On rocks, rare and sterile. Misquah hills, July 5, 1897, no. 496a.

Not previously reported from Minnesota and new to the interior of the United States.

44. **Physcia speciosa** (WULF. ACH.) NYL.

On rocks and more rarely on old wood or trees, infrequent or frequent. Grand Portage island, June 19, 1897, no. 27. Gunflint, June 30, 1897, no. 270 and July 1, 1897, nos. 342 and 348. Misquah hills, July 3, 1897, no. 438, and July 5, 1897, no. 489. Tofte (Carlton peak), July 10, 1897, nos. 571 and 601. Snowbank lake area, July 24, 1897, no. 911. Nos. 348, 438 and 489 fruited.

45. **Physcia ciliaris** (L.) DC.

On rocks or high bluffs, rare. Grand Portage, June 24, 1897, no. 180. Bluffs at south end of South Fowl lake, June 26, 1897, no. 200. Palisades, July 15, 1897, no. 774.

Not previously reported from Minnesota.

46. **Physcia aquila** (ACH.) NYL.

On trees, rare. Two Harbors, July 17, 1897, no. 791.

The only distinct specimen noted and not found farther north.

Not previously reported from Minnesota.

47. **Physcia pulverulenta** (SCHREB.) NYL.

On rocks infrequent or rare, and not often fruited. Grand Portage island, June 23, 1897, nos. 145 and 145a. Grand Portage, June 23, 1897, no. 173. Gunflint, July 2, 1897, no. 374. Snowbank lake area, July 26, 1897, no. 964.

A very variable plant. No. 145a is the typical form with respect to the upper surface of the thallus, being lighter colored than the others and pruinose. Like the others it is usually dark colored below. No. 173 yielded spores of the usual size measuring $\frac{35-42}{18-23}$ mic. and much constricted in the middle. No. 374 gave spores only $\frac{24-35}{9-12}$ mic. and scarcely constricted.

48. **Physcia pulverulenta** (Schreb.) Nyl. var. **leucoleiptes** Tuck.

On rocks and trees, probably rare. Sterile. Grand Portage island, June 23, 1897, no. 119. Misquah hills, July 5, 1897, no. 496. Snowbank lake area, July 27, 1897, no. 966. Thallus black below.

Not previously reported from Minnesota.

49. **Physcia stellaris** (L.) Tuck.

On trees and rocks, frequent or infrequent. Grand Portage island, June 23, 1897, nos. 105 and 142. Gunflint, June 30, 1897, no. 283a, and July 2, 1897, no. 394. Misquah hills, July 5, 1897, no. 460. Tofte (Carlton peak), July 10, 1897, no. 570. Beaver Bay, July 13, 1897, no. 700. Two Harbors, July 17, 1897, no. 801. Ely, July 28, 1897, no. 1012.

Occasionally the tree forms show dark fibrils and even dark thallus below so that the rock growing variety, below, could only be distinguished certainly by the crenulate border of the apothecia. The plant is much more variable than farther south in Minnesota and Iowa. No. 570 yielded apothecia that were somewhat ciliate below, but the plant is white below and otherwise like the present plant rather than *P. obscura* (Ehr.) Nyl.

50. **Physcia stellaris** (L) Tuck. var. **apiola** Nyl.

On rocks, frequent or infrequent. Grand Portage island, June 21, 1897, no. 108. Gunflint, June 30, 1897, no. 284. Misquah hills, July 5, 1897, no. 469. Tofte, July 12, 1897, nos. 640a and 641. Beaver Bay, July 13, 1897, no. 704. Snowbank lake area, July 26, 1897, no. 953.

51. **Physcia tribacia** (Ach.) Tuck.

On rocks, rare and sterile. Grand Portage, June 23, 1897, no. 92. Misquah hills, July 5, 1897, no. 449. Snowbank lake area, July 20, 1897, no. 847.

52. **Physcia hispida** (Schreb. Fr.) Tuck.

On trees, locally infrequent and poorly fruited. Grand Portage island, June 21, 1897, no. 63.

53. **Physcia cæsia** (Hoffm.) Nyl.

On rocks, frequent locally. Sterile. Gunflint, June 30, 1897, nos. 282 and 292.

54. **Physcia obscura** (Ehrh.) Nyl.

On rocks and trees, rare. Grand Portage island, June 23, 1897, no. 145b. Grand Portage, June 24, 1897, no. 172. Tofte, July 12, 1897, no. 642.

No. 145b yielded spores a little large, $\frac{19-33}{9-13}$ mic., and otherwise looks somewhat like *P. pulverulenta* (Schreb.) Nyl., but is black below. Apothecia have hispid borders, and the thallus is much smaller than that of any plants referred to the latter.

55. **Physcia adglutinata** (Floerk.) Nyl.

On trees, rare. Grand Portage, June 23, 1897, nos. 82a and 91a.

56. **Pyxine sorediata** Fr.

On rocks and trees, rare but widely distributed. Collected in fruit three times. Gunflint, July 1, 1897, no. 364, and July 2, 1897, no. 385. Misquah hills, July 3, 1897, no. 437. Tofte, July 10, 1897, no. 633. Palisades, July 15, 1897, no. 746. Two Harbors, July 7, 1897, no. 790. Snowbank lake area, July 24, 1897, no. 912.

57. **Umbilicaria muhlenbergii** (Ach.) Tuck.

On rocks, common or abundant. Grand Portage (Mt. Josephine), June 21, 1897, no. 53. Gunflint, June 30, 1897, nos. 245 and 246. Misquah hills, July 5, 1897, no. 537. Tofte (Carlton peak), July 10, 1897, no. 602. Palisades, July 15, 1897, no. 771. Snowbank lake area, July 24, 1897, no. 938.

58. **Umbilicaria vellea** (L.) Nyl.

On rocks, common or frequent. Grand Portage (Mt. Josephine), June 21, 1897, no. 57, and June 24, 1897, no. 178. Gunflint, July 1, 1897, no. 367. Misquah hills, July 3, 1897, no. 430, and July 5, 1897, no. 538. Palisades, July 15, 1897, no. 766. Snowbank lake area, July 24, 1897, no. 931.

59. **Umbilicaria dillenii** Tuck.

On rocks, common. Grand Portage, June 24, 1897, no. 170. Gunflint, July 1, 1897, no. 370. Misquah hills, July 3, 1897, no. 429, and July 5, 1897, no. 445. Tofte (Carlton peak), July

10, 1897, no. 599. Palisades, July 15, 1897, no. 775. Snowbank lake area, July 24, 1897, no. 937.

60. **Umbilicaria pustulata** (L.) Hoffm. var. **papulosa** Tuck.

On rocks, rare to frequent. Spores reaching 100 mic. in length. Gunflint, July 1, 1897, no. 371. Misquah hills, July 3, 1897, no. 542. Palisades, July 15, 1897, no. 756. Snowbank lake area, July 24, 1897, no. 932.

61. **Umbilicaria hyperborea** Hoffm.

On rocks, rare, Grand Portage (Mt. Josephine), June 23, 1897, no. 104.

Not previously reported from Minnesota and new to the interior within the United States.

62. **Sticta amplissima** (Scop.) Mass.

On trees or rocks, rare or infrequent. Grand Portage, June 23, 1897, no. 115. Tofte (Carlton peak), July 10, 1897, no. 609. Beaver Bay, July 14, 1897, no. 720. Two Harbors, July 17, 1897, no. 802. Ely, July 28, 1897, no. 981.

63. **Sticta pulmonaria** (L.) Ach.

On trees or rocks, common or frequent. Grand Portage island, June 19, 1897, no. 23. Rose lake, June 28, 1897, no. 225. Gunflint, July 1, 1897, no. 365. Misquah hills, July 3, 1897, no. 443. Tofte (Carlton peak), July 10, 1897, no. 396. Beaver Bay, July 14, 1897, no. 724. Two Harbors, July 17, 1897, no. 795. Snowbank lake area, July 19, 1897, no. 808. Ely, July 28, 1897, no. 984.

64. **Sticta limbata** (Sm.) Ach.

On trees, very rare. Tofte, July 10, 1897, no. 626. Only two plants collected with thallus also much like that of the European *Sticta fuliginosa*. Spores brown, two-celled, constricted, $\frac{19-23}{8-9}$ mic.

Not previously reported from Minnesota and only once from North America. (Oregon, by J. W. Eckfeldt.)

65. **Sticta crocata** (L.) Ach.

On trees and rocks, rare. Tofte (Carlton peak), July 10, 1897, no 597. Beaver Bay, July 13, 1897, no. 685. Snowbank lake area, July 24, 1897, no. 940.

Not previously reported from Minnesota and new to the interior within the United States.

66. **Sticta scorbiculata** (Scop.) Ach.

Mossy rocks and trees, rare except at Grand Portage where frequent. Grand Portage, June 24, 1897, no. 176. Tofte, July 10, 1897, no. 629.

Not previously reported from Minnesota and new to the interior of North America.

67. **Nephroma tomentosum** (Hoffm.) Koerb.

On rocks and trees, frequent. Grand Portage island, June 19, 1897, no. 26. Misquah hills, July 5, 1897, no. 541. Tofte, July 10, 1897, no. 634. Snowbank lake area, July 19, 1897, no. 803.

Not previously reported from Minnesota and new to the interior of North America.

68. **Nephroma helveticum** Ach.

On rocks and occasionally on trees and earth, frequent. Grand Portage island, June 23, 1897, no. 133. Gunflint June, 29, 1897, no. 235, and June 30, 1897, no. 250. Misquah hills, July 5, 1897, no. 540. Beaver Bay, July 14, 1897, no. 740. Tofte (Carlton peak), July 10, 1897, no. 605. Snowbank lake area, July 24, 1897, no. 921, and July 26, 1897, no. 961. Ely, July, 28, 1897, no. 1005.

69. **Nephroma lævigatum** Ach.

On trees, rare. Misquah hills, July 5, 1897, no. 426. Two Harbors, July 17, 1897, no. 799.

Not previously reported from Minnesota.

70. **Nephroma lævigatum** Ach. var. **parile** Nyl.

On rocks, locally common. Grand Portage, June 23, 1897, no. 113.

Not previously reported from Minnesota.

71. **Peltigera venosa** (L.) Hoffm.

On earth and mossy rocks, rare, spores reaching 60 mic. in length and occasionally five-celled. Grand Portage, June 23, 1897, no. 150. Portage at south end of South Fowl lake, June 26, 1897, no. 207.

72. **Peltigera aphthosa** (L.) Hoffm.

On earth or rocks, common or frequent. Grand Portage Island, June 24, 1897, no. 177. Gunflint, June 30, 1897, no. 248. Misquah hills, July 5, 1897, no. 526. Palisades, July 15, 1897, no. 770. Snowbank lake area, July 19, 1897, no. 829.

73. **Peltigera horizontalis** (L.) HOFFM.

On earth, frequent or common. Grand Portage island, June 19, 1897, no. 30 and June 23, 1897, no. 121. Gunflint, June 30, 1897, no. 247, and July 1, 1897, nos. 338 and 360. Misquah hills, July 3, 1897, no. 441. Tofte, July 12, 1897, nos. 630 and 631. Beaver Bay, July 14, 1897, no. 723. Palisades, July 15, 1897, no. 761. Snowbank lake area, July 24, 1897, nos. 917 and 918. Part of the plants placed here agree somewhat with those reported elsewhere for Iowa and Minnesota as *P. pulverulenta* (Tayl.) Nyl., but though the sterile forms previously seen differ considerably from the fertile ones herein reported perhaps all must eventually be placed here. The sterile forms, occasionally light colored below, are crisped and broken probably from unfavorable conditions which prevented their fruiting.

Not previously reported from Minnesota.

74. **Peltigera polydactyla** (NECK.) HOFFM.

On earth, common. Spores reaching 110 mic. Grand Portage island, June 23, 1897, nos. 140 and 144. Gunflint, July 1, 1897, no. 336. Misquah hills, July 5, 1897, no. 536. Beaver Bay, July 14, 1897, no 726. Snowbank lake area, July 24, 1897, no. 929, and July 27, 1897, no. 971.

75. **Peltigera canina** (L.) HOFFM. var. **spuria** ACH.

On earth, frequent or common. Grand Portage island, June 19, 1897, no. 29. Grand Portage (Mt. Josephine), June 21, 1897, no. 54. Gunflint, July 1, 1897, no. 323. Beaver Bay, July 13, 1897, no. 663. Palisades, July 13, 1897, no. 760. Snowbank lake area, July 24, 1897, no. 943.

76. **Peltigera canina** (L.) HOFFM. var **sorediata** SCHAER.

On earth, frequent. Grand Portage (Mt. Josephine), June 23, 1897 no. 118a. Gunflint, July 1, 1897, no. 343. Misquah hills, July 5, 1897, no. 535. Tofte (Carlton peak), July 10, 1897, no. 589. Beaver Bay, July 13, 1897, no. 693. Snowbank lake area, July 24, 1897, no. 902. Ely, July 28, 1897, no. 976.

77. **Solorina saccata** (L.) ACH.

On earth, rare. Grand Portage island, June 24, 1897, no. 179. Not previously reported from Minnesota and new to the interior of North America.

78. **Pannaria languinosa** (ACH.) KOERB.

On rocks, common. Grand Portage island, June 17, 1897, no. 1. South Fowl lake, June 26, 1897, no. 195. Gunflint, June 30, 1897, no. 272. Misquah hills, July 3, 1897, no. 435, and July 5, 1897, no. 457. Tofte (Carlton peak), July 10, 1897, no. 561a. Beaver Bay, July 13, 1897, no. 691. Snowbank lake area, July 19, 1897, no. 824. Nos. 195 and 457 showing the bright sulphur-colored plant common in Europe and only noted in North America by the present writer in the second paper of this series.

79. **Pannaria microphylla** (SW.) DELIS.

On rocks, frequent on Grand Portage island, June 19, 1897, no. 22. Gunflint, July 1, 1897, no. 330. Beaver Bay, July 13, 1897, no. 684. Ely, July 28, 1897, no. 987.

80. **Pannaria lepidiota** TH. FR.

On rocks and wood, infrequent. Grand Portage, June 24, 1897, no. 175. Gunflint, July 2, 1897, no. 372. Misquah hills, July 5, 1897, nos. 463 and 479. Tofte (Carlton peak), July 10, 1897, no. 582. Snowbank lake area, July 24, 1897, no. 908.

Not previously reported from Minnesota.

81. **Pannaria flabellosa** TUCK.

On rocks, rare. Grand Portage island, June 23, 1897, no. 128. Sterile, but having the narrow linear lobed thallus and blue-black hypothallus. The thallus does not show the expanded and striated lobes at circumference.

Not previously reported from Minnesota and new west of New England.

82. **Pannaria nigra** (HUDS.) NYL.

On rocks, rare. Gunflint, July 1, 1897, no. 347.

83. **Ephebe pubescens** FR.

On rocks, rare, sterile. Palisades, July 13, 1897, no. 745. Snowbank lake area, July 24, 1897, no. 901.

Not previously reported from Minnesota and new to the interior of North America.

84. **Ephebe solida** BORN. (?)

On rocks, rare and sterile. Misquah hills, July 5, 1897, no. 488. Beaver Bay, July 13, 1897, no. 683. Snowbank lake area, July 20, 1897, no. 849.

A short form growing in small dense tufts.

85. **Collema pycnocarpum** Nyl.

On trees, rare. Snowbank lake area, July 27, 1897, nos. 968 and 974.

86. **Collema flaccidum** Ach. (?)

On high rocks, rare. Misquah hills, July 5, 1897, no. 495. Sterile, but with the thallus corresponding with tree forms farther south, except that the plant is larger.

87. **Collema nigrescens** (Huds.) Ach.

On trees, especially *Populus*, common or frequent. Grand Portage, June 19, 1897, no. 36, and June 23, 1897, no. 101. Rose lake, June 28, 1897, no. 221. Gunflint, July 30, 1897, no. 266. Misquah hills, July 5, 1897, no. 483. Beaver Bay, July 15, 1897, no. 783. Snowbank lake area, July 19, 1897, no. 822, and July 21, 1879, no. 874. Ely, July 28, 1897, no. 1014.

88. **Collema furvum** (Ach.) Nyl?

On wet rocks, frequent. Grand Portage island, June 23, 1897; no. 156. Tofte, July 12, 1897, no. 646. Not typical.

Not previously reported from Minnesota.

89. **Leptogium lacerum** (Sw.) Fr.

On rocks, rare and sterile. Snowbank lake area, July 21, 1897, no. 867.

90. **Leptogium lacerum** (Sw.) Fr. var. **pulvinatum** Moug. and Nestl.

On rocks, rare. Snowbank lake area, July 29, 1897, no. 965.

Not previously reported from Minnesota.

91. **Leptogium tremelloides** (L.) Fr.

On rocks and rarely on trees. Widely distributed, but usually rare locally. Portage between South Fowl lake and Pigeon river, June 26, 1897, no. 208. Gunflint, July 1, 1897, nos. 349 and 358. Misquah hills, July 3, 1897, no. 424. Beaver Bay, July 15, 1897, no. 781. Snowbank lake area, July 20, 1897, no. 843, July 26, 1897, no. 962, and July 27, 1897, no. 974a. Ely, July 28, 1897, nos. 977 and 1008.

92. **Leptogium myochroum** (Ehrh., Schaer.) Tuck.

On trees and rocks, frequent. Grand Portage island, June 19, 1897, no. 24. Gunflint, July 1, 1897, no. 341. Tofte (Carlton peak), July 10, 1897, no. 598. Snowbank lake area July 19, 1897, no. 820.

Not previously reported from Minnesota.

93. **Leptogium myochroum** (EHRH., SCHAER.) TUCK. var. **tomentosum** SCHAER.

On trees, rare. Tofte (Carlton peak), July 10, 1897, no. 559. Not previously reported from Minnesota.

94. **Placodium elegans** (LINK.) DC.

On rocks, common. Grand Portage, June 21, 1897, no. 69. Grand Portage island, June 23, 1897, nos. 93 and 98. Gunflint, June 30, 1897, no. 294, and July 1, 1897, no. 328. Misquah hills, July 5, 1897, no. 444. Palisades, July 15, 1897, no. 747. Snowbank lake area, July 22, 1897, no. 887, no. 444, looking toward the next in having orange-red apothecia.

95. **Placodium murorum** (HOFFM.) DC.

On rocks, rare. Misquah hills, July 5, 1897, no. 450. Not previously reported from Minnesota.

96. **Placodium murorum** (HOFFM.) DC. var. **miniatum** TUCK.

On rocks, rare. Sterile. Grand Portage, June 23, 1897, no. 88. Not previously reported from Minnesota.

97. **Placodium cinnabarinum** (ACH.) ANZ.

On rocks, common at the one locality. Gunflint, July 2, no. 378.

98. **Placodium citrinum** (HOFFM.) LEIGHT.

On rocks, infrequent. No. 68 well fruited but with thallus nearly obsolete in some specimens. Grand Portage island, June 21, 1897, no. 68. Grand Portage, June 23, 1897, no. 117. Misquah hills, July 5, 1897, no. 461.

99. **Placodium aurantiacum** (LIGHTF.) NAEG. and HEPP.

On rocks, rare at first locality, frequent at second. Grand Portage island, June 23, 1897, no. 127. Gunflint, June 30, 1897. nos. 296 and 298, and July 2, 1897, no. 389. Beaver Bay, July 13, 1897, no. 661. No. 296 with a white thallus and otherwise not typical, but I can place it nowhere else.

100. **Placodium cerinum** (HEDW.) NAEG. and HEPP.

On trees, frequent. Grand Portage, June 23, 1897, no. 84. Gunflint, June 30, 1897, no. 253, and July 2, 1897, no. 392. Beaver Bay, July 13, 1897, no. 669.

101. **Placodium cerinum** (HEDW.) NAEG. and HEPP. var. **pyracea** NYL.

On old wood, common locally. Beaver Bay, July 13, 1897, no. 682.

102. **Placodium vitellinum** (EHRH.) NAEG. and HEPP.

On old wood, frequent. Beaver Bay, July 13, 1897, no. 660. Spores simple or two-celled and reaching 30 in each ascus.

103. **Placodium vitellinum** (EHRH.) NAEG. and HEPP. var. **aurellum** ACH.

On rocks, common at Gunflint, rare elsewhere. Grand Portage island, June 24, 1897, no. 163. Gunflint, June 30, 1897, no. 279, and July 1, 1897, no. 329. Tofte (Carleton peak), July 10, 1897, no. 618. Snowbank lake area, July 24, 1897, no. 903. Spores reaching 20 in asci.

104. **Lecanora rubina** (VILL.) ACH.

On rocks, common or frequent. Grand Portage (Mt. Josephine), June 19, 1897, no. 47. Grand Portage island, June 21, 1897, no. 73. Gunflint, June 30, 1897, no. 265. Misquah hills, July 5, 1897, no. 486. Beaver Bay, July 13, 1897, no. 705. Snowbank lake area, July 26, 1897, no. 954.

105. **Lecanora rubina** (VILL.) ACH. var. **heteromorpha** ACH.

On rocks, frequent locally. Grand Portage (Mt. Josephine), June 19, 1897, no. 47a. Gunflint, July 1, 1897, no. 326. Palisades, July 15, 1897, no. 748.

Not previously reported from Minnesota.

106. **Lecanora muralis** (SCHREB.) SCHAER. var. **saxicola** SCHAER.

On rocks, common or frequent. Grand Portage island, June 21, 1897, no. 75. Rose lake, June 29, 1897, no. 224. Misquah hills, July 5, 1897, no. 513. Tofte, July 12, 1897, no. 643.

107. **Lecanora muralis** (SCHREB.) SCHAER. var. **diffracta** FR.

On rocks, rare. Grand Portage (Mt. Josephine), June 19, 1897, no. 46.

Not previously reported from Minnesota.

108. **Lecanora pallida** (SCHREB.) SCHAER.

On trees, infrequent. Gunflint, July 1, 1897, no. 337.

Not previously reported from Minnesota.

109. **Lecanora frustulosa** (DICKS.) MASS.

On rocks, frequent. Grand Portage, June 21, 1897, no. 78, and June 23, 1897, no. 153. Gunflint, July 2, 1897, no. 376. Beaver Bay, July, 13, 1897, no. 706.

Not previously reported from Minnesota and new to the interior of North America.

110. **Lecanora sordida** (PERS.) TH. FR.

Rocks, common at the last two locations which were high bluffs. Grand Portage, June 24, 1897, no. 185. South Fowl lake, June 26, 1897, no. 198. Misquah hills, July 5, 1897, nos. 465 and 505.

Not previously reported from Minnesota and new to the interior of North America.

111. **Lecanora subfusca** (L.) ACH.

On trees and rocks, common on the former. Grand Portage, June 23, 1897, no. 131. South end of South Fowl lake, June 26, 1897, no. 202. Misquah hills, July 5, 1897, no. 500. Gunflint, June 30, 1897, no. 274, and July 1, 1897, no. 305. Tofte (Carlton peak), July 10, 1897, nos. 588 and 595. Beaver Bay, July 15, 1897, no. 780. Snowbank lake area, July 19, 1897, no. 825, and July 21, 1897, no. 855.

112. **Lecanora subfusca** (L.) ACH. var. **hypnorum** SCHAER.

Among moss on a cedar tree, rare. Misquah hills, July 5, 1897, no. 494a. Not previously reported from Minnesota.

113. **Lecanora subfusca** (L.) ACH. var. **coilocarpa** Ach.

On trees and rocks, frequent. Grand Portage island, June 21, 1897, no. 67. Gunflint, June 30, 1897, no. 301, and July 1, 1897, no. 339. Misquah hills, July 5, 1897, no. 481. Beaver Bay, July 13, 1897, no. 698.

114. **Lecanora varia** (EHRH.) NYL.

On rocks, rare or infrequent and some specimens perhaps approaching var. *polytropa* Nyl. Grand Portage, June 19, 1897, no. 41. Gunflint, July 1, 1897, no. 307, and July 2, 1897, no. 380.

115. **Lecanora varia** (EHRH.) NYL. var. **sæpincola** FR.

On wood, common at first locality. Beaver Bay, July 14, 1897, no. 742. Snowbank lake area, July 22, 1897, no. 889.

Not previously reported from Minnesota.

116. **Lecanora varia** (EHRH.) NYL. var. **symmicta** ACH.

On old wood, rare. Grand Portage island, June 18, 1897, no. 12. Gunflint, July 2, 1897, no. 400. Tofte (Carlton peak), July 10, 1897, no. 580.

117. **Lecanora hageni** ACH.

On rocks, rare. Gunflint, July 1, 1897, no. 357.

118. **Lecanora hageni** ACH. var. **sambuci** (PERS.) TUCK.

On trees common locally. Grand Portage island, June 19, 1897, no. 25. Misquah hills, July 5, 1897, no. 501. Tofte (Carlton peak), July 10, 1897, no. 575.

A puzzling plant with exciple commonly entire or excluded and looking quite as much like forms of *L. subfusca* (L.) Ach. or *L. varia.* (Ehrh.) Nyl. Spores reaching sixteen in asci.

Not previously reported from Minnesota and new to the interior of North America.

119. **Lecanora elatina** ACH.

On trees, rare. Tofte, July 10, 1897, no. 638.

Not previously reported from Minnesota and new to the interior of North America.

120. **Lecanora pallescens** (L.) SCHAER.

On trees, infrequent or rare, but widely distributed. Misquah hills, July 3, 1897, no. 412, and July 5, 1897, no. 494. Tofte (Carlton peak), July 10, 1897, no. 592. Beaver Bay, July 13, 1897, no. 674. Two Harbors, July 17, 1897, no. 798. Snowbank lake area, July 21, 1897, no. 864, and July 27, 1897, no. 973.

Not previously reported from Minnesota.

121. **Lecanora tartarea** (L.) ACH.

On rocks, rare. Ely, July 28, 1897, no. 988.

Not previously reported from Minnesota.

122. **Lecanora cinerea** (L.) SOMMERF.

On rocks, common or abundant. The thallus varying in color from ash-color to a dull black. Grand Portage (Mt. Josephine), June 19, 1897, no. 39. Grand Portage island, June 21, 1897, no. 74. Gunflint, June 30, 1897, nos. 285, 293a, 295 and 300. Misquah hills, July 5, 1897, nos. 458, 468 and 493a. Tofte (Carlton peak), July 10, 1897, nos. 615 and 622. Palisades, July 15, 1897, no. 752. Beaver Bay, July 15, 1897, no. 778. Snowbank lake area, July 20, 1897, no. 833. Ely, July 28, 1897, no. 990.

123. **Lecanora cinerea** (L.) SOMMERF. var. **lævata** FR.

On rocks, rare. Grand Portage, June 23, 1897, no. 94. Gunflint, June 30, 1897, no. 286. Misquah hills, July 5, 1897, no. 471. Snowbank lake area, July 20, 1897, no. 836.

124. **Lecanora cinerea** (L.) SOMMERF. var. **gibbosa** NYL.

On rocks, rather rare. Grand Portage island, June 23, 1897, no. 79. Gunflint, July 1, 1897, no. 309a. Misquah hills, July 5, 1897, no. 472.

125. **Lecanora calcarea** (L.) SOMMERF. (?)

On rocks, rare. Thallus almost obsolete and spores only $\frac{10-14}{5-7}$ mic. Beaver Bay, July 13, 1897, no. 707.

Not previously reported from Minnesota.

126. **Lecanora calcarea** (L.) SOMMERF. var. **contorta** FR.

On rocks, rare. Grand Portage island, June 23, 1897, no. 155.

Not previously reported from Minnesota.

127. **Lecanora fuscata** (SCHRAD.) TH. FR.

On rocks, frequent. Grand Portage (Mt. Josephine), June 19, 1897, no. 44a. Grand Portage, June 21, 1897, no. 71. Gunflint, July 1, 1897, no. 331.

128. **Lecanora fuscata** (SCHRAD.) TH. FR. var. **rufescens** TH. FR.

On rocks, frequent at second locality. Misquah hills, July 5, 1897, no. 446. Beaver Bay, July 14, 1897, no. 718, and July 15, 1897, no. 777.

Not previously reported from Minnesota.

129. **Rinodina oreina** (ACH.) MASS.

On rocks, rare, preferring high perpendicular rocks or larger masses of talus. No. 750 is an unusually coarse form, but must be referred here. South end of South Fowl lake, June 26, 1897, no. 203. Misquah hills, July 5, 1897, no. 518. Palisades, July 15, 1897, nos. 750 and 753. Snowbank lake area July 20, 1897, no. 854.

130. **Rinodina ascociscana** TUCK.

On trees, rare. Gunflint, July 1, 1897, no. 340. Tofte (Carlton peak), July 10, 1897, no. 594.

Not previously reported from Minnesota.

131. **Rinodina sophodes** (ACH.) NYL.

Abundant on drift pebbles at Beaver Bay, infrequent on wood elsewhere. Grand Portage, June 23, 1897, no. 95. Tofte, July 12, 1897, no. 651. Beaver Bay, July 13, 1897, no. 702. Snowbank lake area, July 20, 1897, no. 853.

132. **Rinodina sophodes** (ACH.) NYL. var. **confragosa** NYL.

On wood, rare. Spores 25 to 34 mic. in length. Snowbank lake area, July 21, 1897, no. 875.

Not previously reported from Minnesota.

133. **Pertusaria velata** (TURN.) NYL.

On trees, infrequent. Portage, between Rose and Rove lakes, June 27, 1897, no. 210a. Tofte (Carlton peak), July 10, 1897, no. 577. Ely, July 28, 1897, no. 1017.

134. **Pertusaria multipuncta** (TURN.) NYL.

On trees, frequent at second locality. Tofte (Carlton peak), July 10, 1897, no. 611. Snowbank lake area, July 28, 1897, no. 900.

135. **Pertusaria multipunctata** (TURN.) NYL. var. **lævigata** TURN. and BORR.

On trees, probably frequent. Grand Portage, June 23, 1897, no. 158. Rose lake, June 28, 1897, no. 217a. Gunflint, July 2, 1897, no. 389a. Misquah hills, July 5, 1897, no. 478.

Not previously reported from Minnesota and new to North America.

136. **Pertusaria communis** DC.

On trees, nearly always cedars, common or frequent. Portage, between Rose and Rove lakes, June 27, 1897, no. 210. Rose lake, June 28, 1897, no. 217. Gunflint, July 1, 1897, no. 336, Misquah hills, July 7, 1897, nos. 453 and 499. Beaver Bay, July 13, 1897, no. 664, and July 15, 1897, no. 782. Snowbank lake area, July 21, 1897, nos. 870 and 888.

137. **Pertusaria** sp.

On trees. Spores nearly like the above in the few apothecia not transformed into soredia. Thallus lighter colored at circumference with frequent two or three dark lines near circumference. Misquah hills, July 3, 1897, no. 410. Beaver Bay, July 15, 1897, no. 688. Snowbank lake area, July 19, 1897, no. 826.

138. **Pertusaria leioplaca** (ACH.) SCHAER.

On trees, widely distributed but seldom common in any locality. Grand Portage, June 23, 1897, no. 91. Portage between North Fowl lake and Moose lake, June 26, 1897, no. 192. Rose lake, June 28, 1897, no. 218. Gunflint, June 30, 1897, no. 275, and July 2, 1897, no. 399. Misquah hills, July 5, 1897, no. 491a. Beaver Bay, July 15, 1897, no. 784. Ely, July 28, 1897, no. 1010. Varying greatly according to substratum. On young trees with smooth bark the thallus is thin and smooth and the ostioles frequently indistinct. On older trees with rough bark the thallus is thicker and broken, and the apothecia are falsely lecanoroid. The last feature is due no doubt to great age of these plants which began growth when the trees were young. The extremes appear macroscopically like distinct species.

Not previously reported from Minnesota.

139. **Pertusaria pustulata** (ACH.) NYL.

On trees, infrequent. Rose lake, June 28, 1897, no. 228. Gunflint, July 1, 1897, no. 310. Misquah hills, July 3, 1897, no. 418.

140. **Pertusaria glomerata** (ACH.) SCHAER.

On rocks, very rare. Misquah hills, July 5, 1897, no. 490.

Not previously reported from Minnesota and new to the interior of North America.

141. **Gyalecta fagicola** (HEPP.) TUCK.

On trees, rare. Snowbank lake area, July 22, 1897, no. 880.

Not previously reported from Minnesota and new to west of of New England.

142. **Urceolaria scruposa** (L.) NYL.

On rocks, rare or infrequent, but widely distributed and no. 126 with thallus approaching var. *gypsacea* Nyl. Grand Portage island, June 25, 1897, no. 126. Gunflint, June 30, 1897, no. 302. Misquah hills, July 5, 1897, no. 473. Beaver Bay, July 13, 1897, no. 701. Snowbank lake area, July 23, 1897, no. 899. Ely, July 28, 1897, no. 978.

143. **Stereocaulon coralloides** FR.

On rocks, frequent. Tofte (Carlton peak), July 10, 1897. no. 549.

Not previously reported from Minnesota and new to the interior of North America.

144. **Stereocaulon paschale** (L.) FR.

On earth among rocks, common. Grand Portage (Mt. Josephine), June 19, 1897, no. 49. Grand Portage island, June 21, 1897, no. 50. Gunflint, June 30, 1897, no. 233. Misquah hills, July 5, 1897, no. 482. Beaver Bay, July 13, 1897, no. 689. Palisades, July 15, 1897, no. 758. Snowbank lake area, July 24, 1897, no. 927. No. 49 seems to approach the above. Also no. 50 has the stout podetia of *S. tomentosum* (Fr.) Th. Fr. and is somewhat tomentose. Yet it appears nearer herb. specimens of the above.

145. **Cladonia symphycarpa** Fr. var. **epiphylla** (Ach.) Nyl.

In crevices in rocks, rare. Habitat unusual but thallus too large for *C. cæspiticia* (Pers.) Fl. Gunflint, July 1, 1897, no. 363.

Not previously reported from Minnesota.

146. **Cladonia mitrula** Tuck.

On earth, rare. Beaver Bay, July 15, 1897, no. 694.

147. **Cladonia cariosa** (Ach.) Spreng.

On earth, probably frequent. Grand Portage island, June 23, 1897, nos. 120 and 146. Gunflint, July 1, 1897, no. 324. Misquah hills, July 5, 1897, nos. 509 and 533. Tofte (Carlton peak), July 10, 1897, no. 606. Beaver Bay, July 14, 1897, nos. 737 and 739.

The forms listed here seem to me to be partly intermediate between this and the last having the habit of this, but some are rather small with the squamules usually small. *C. mitrula* Tuck. is the common form in southern Minnesota, but the better development of this region runs into the present species. Of the specimens here listed no. 146 is the best representative of the species and no. 120 the poorest. Some of the smaller approaches *C. symphycarpa* Fr., which is itself a doubtful species.

148. **Cladonia decorticata** Floerk.

On earth, rare. Beaver Bay, July 14, 1897, no. 738. Not previously reported from Minnesota and new to west of New England.

149. **Cladonia pyxidata** (L.) Fr.

On earth, common. Grand Portage island, June 19, 1897, no. 32. Gunflint, July 1, 1897, nos. 333 and 352. Misquah hills, July 5, 1897, no. 534. Tofte (Carlton peak), July 10, 1897, nos. 567 and 568. Beaver Bay, July 14, 1897, no. 735. Snowbank lake area, July 21, 1897, no. 868, and July 27, 1897, no. 972.

150. **Cladonia fimbriata** (L.) Fr.

On earth, rare. Gunflint, June 30, 1897, no. 259.

Not previously reported from Minnesota.

151. **Cladonia fimbriata** (L.) Fr. var. **tubæformis** Fr.

On dead wood and earth, common. Grand Portage island, June 23, 1897, no. 129. Gunflint, June 30, 1897, no. 268. Misquah hills, July 3, 1897, no. 439. Tofte (Carlton peak), July 10, 1897, no. 561. Snowbank lake area, July 24, 1897, no. 930.

152. **Cladonia fimbriata** (L.) Fr. var. **radiata** Fr.

On earth and old wood, frequent. Grand Portage island, June 19, 1897, no. 33 and June 24, 1897, no. 162. Gunflint, June 30, 1897, no. 234. Snowbank lake area, July 20, 1897, no. 840.

Not previously reported from Minnesota.

153. **Cladonia gracilis** (L.) Nyl.

On earth, common or abundant and extremely variable. Grand Portage island, June 19, 1897, no. 35. Gunflint, July 1, 1897, nos. 325, 344 and 345. Misquah hills, July 5, 1897, nos. 508 and 522. Tofte (Carlton peak), July 10, 1897, nos. 550, 564 and 604. Beaver Bay, July 14, 1897, no. 734. Snowbank lake area, July 21, 1897, no 876 and July 24, 1897, nos. 922 and 923.

154. **Cladonia gracilis** (L.) Nyl. var. **verticillata** Fr.

On earth, rare, Grand Portage island, June 19, 1897, nos. 35b and 35d. Tofte (Carlton peak), July 10, 1897, no. 625.

155. **Cladonia gracilis** (L.) Nyl. var. **symphycarpia** Tuck.

On earth, infrequent, possibly as near *C. degenerans* Floerk. Grand Portage island, June 19, 1897, no. 35a.

Not previously reported from Minnesota.

156. **Cladonia gracilis** (L.) Nyl. var. **cervicornis** Floerk.

On earth, rare. Gunflint, June 30, 1897, no. 231.

Not previously reported from Minnesota.

157. **Cladonia gracilis** (L.) Nyl. var. **hybrida** Schaer.

On earth, common. Grand Portage island, June 19, 1897, no. 35c. Gunflint, July 1, 1897, no. 346. Misquah hills, July 3, 1897, no. 433. Snowbank lake area, July 19, 1897, no. 821, and July 24, 1897, no. 905.

158. **Cladonia turgida** (Ehrh.) Hoffm.

On earth, common at Gunflint. Gunflint, June 30, 1897, nos. 241 and 252. Snowbank lake area, July 24, 1897, no. 928.

Not previously reported from Minnesota.

159. **Cladonia turgida** (Ehrh.) Hoffm. var. **conspicua** (Schaer.) Nyl.

On earth, frequent. Rose lake, June 28, 1897, no. 237. Misquah hills, July 3, 1897, no. 425, and July 5, 1897, no. 525. Tofte, (Carlton peak), July 10, 1897, nos. 603 and 637.

Not previously reported from Minnesota.

160. **Cladonia squamosa** HOFFM.

On earth, common or abundant. Grand Portage island, June 24, 1897, no. 165. Gunflint, June 30, 1897, no. 232, and July 1, 1897, no. 350, and July 2, 1897, no. 384. Misquah hills, July 5, 1897, no. 529. Tofte, July 12, 1897, nos. 628 and 632. Beaver Bay, July 14, 1897, no. 719. Above Palisades, July 15, 1897, no. 772. Snowbank lake area, July 24, 1897, nos. 913, 919 and 924. Ely, July 28, 1897, no. 995.

161. **Cladonia squamosa** HOFFM. var. **phyllocoma** RABENH.

On earth, frequent. Grand Portage island, June 23, 1897, no. 141. Misquah hills, July 5, 1897, no. 459. Snowbank lake area, July 24, 1897, nos. 939 and 942.

Not previously reported from Minnesota and new to North America.

162. **Cladonia cornuta** (L.) FR.

On earth, rare. Grand Portage island, June 24, 1897, no. 159. Misquah hills, July 5, 1897, no. 511.

Not previously reported from Minnesota.

163. **Cladonia delicata** (EHRH.) FL.

On old wood, rare. Beaver Bay, July 13, 1897, no. 692.

164. **Cladonia cæspiticia** (PERS.) FL.

On old wood, rare. Tofte (Carlton peak), July 10, 1897, no. 586.

165. **Cladonia furcata** (HUDS.) FR.

On earth, frequent. Gunflint, June 30, 1897, nos. 236 and 237. Misquah hills, July 5, 1897, no. 524. Above Palisades, July 15, 1897, no, 767. Snowbank lake area, July 24, 1897, no. 914.

166. **Cladonia furcata** (HUDS.) FR. var. **crispata** FL.

On earth, common locally. Grand Portage, June 24, 1897, no. 168. Gunflint, June 30, 1897, no. 249. Palisades, July 15, 1897, no. 757.

167. **Cladonia rangiferina** (L.) HOFFM.

On earth, abundant or common. Grand Portage island, June 17, 1897, no. 2, and June 23, 1897, 135. Grand Portage (Mt. Josephine), June 19, 1897, no. 48. Gunflint, June 30, 1897, no. 244. Misquah hills, July 5, 1897, no. 521. Tofte, (Carlton peak), July 10, 1897, no. 548. Beaver Bay, July 14, 1897, no. 732. Palisades, July 15, 1897, no. 759. Snowbank lake area, July 24, 1897, no. 926.

168. **Cladonia rangiferina** (L.) HOFFM. var. **sylvatica** L.

On earth, frequent. Misquah hills, July 5, 1897, no. 531. Tofte (Carlton peak), July 10, 1897, no. 553. Snowbank lake area, July 24, 1897, nos. 915 and 936.

169. **Cladonia rangiferina** (L.) HOFFM. var. **alpestris** L.

On earth, common locally. Grand Portage, June 24, 1897, no. 171. Gunflint, July 1, 1897, no. 351. Above Palisades, July 15, 1897, no. 773.

170. **Cladonia amaurocræa** (FL.) SCHAER.

On earth and rocks, common or frequent. Grand Portage (Mt. Josephine), June 21, 1897, no. 52. Grand Portage island, June 24, 1897, no. 164. Gunflint, June 30, 1897, no. 243. Misquah hills, July, 5, 1897, nos. 530 and 532. Tofte (Carlton peak), July, 10, 1897, no. 552. Palisades, July 15, 1897, no. 769. Snowbank lake area, July 24, 1897, nos. 935 and 941.

Not previously reported from Minnesota.

171. **Cladonia uncialis** (L.) FR.

On earth, frequent or common. Grand Portage (Mt. Josephine), June 21, 1897, no. 55. Grand Portage, June 24, 1897, no. 167. Gunflint, June 30, 1897, no. 239. Misquah hills, July 5, 1897, no. 475. Misquah hills, July 5, 1897, no. 528. Tofte (Carlton peak), July 10, 1897, no. 551. Beaver Bay, July 14, 1897, no. 727. Palisades, July 15, 1897, no. 764. Snowbank lake area, July 24, 1897, no. 933.

172. **Cladonia cornucopioides** (L.) FR.

On earth, rare but widely distributed. Grand Portage, June 24, 1897, no. 166. Gunflint, July 30, 1897, no. 238. Misquah hills, July 5, 1897, nos. 497 and 527. Tofte (Carlton peak), July 10, 1897, no. 563. Above Palisades, July 15, 1897, no. 754.

173. **Cladonia deformis** (L.) HOFFM.

On earth, rare. Grand Portage island, June 23, 1897, no. 151.

Not previously reported from Minnesota and new to the interior of North America.

174. **Cladonia digitata** (L.) HOFFM.

On an old stump, rare. Tofte, July 12, 1897, no. 655.

Not previously reported from Minnesota and new to the interior of North America.

175. **Cladonia macilenta** (Ehrh.) Hoffm.

On old wood and earth, rare. Misquah hills, July 5, 1897, no. 510. Above Palisades, July 15, 1897, no. 776.

176. **Cladonia cristatella** Tuck.

On earth and old wood, abundant. Grand Portage island, June 18, 1897, no. 31. Gunflint, July 1, 1897, nos. 322 and 332. Misquah hills, July 3, 1897, no. 417. Tofte (Carlton peak), July 10, 1897, no. 610. Beaver Bay, July 14, 1897, no. 736. Snowbank lake area, July 19, 1897, no. 827.

177. **Bæomyces byssoides** (L.) Schaer.

On rocks, rare. Grand Portage island, June 21, 1897, no. 109.

Not previously reported from Minnesota, and new to the interior of North America.

178. **Bæomyces æruginosus** (Scop.) DC.

On rotton wood, common. Grand Portage island, June 18, 1897, no. 16. Gunflint, July 1, 1897, no. 309. Misquah hills, July 3, 1897, no. 404. Tofte, July 12, 1897, no. 639. Beaver Bay, July 14, 1897, no. 721. Snowbank lake area, July 19, 1897, no. 823.

Not previously reported from Minnesota, and new to the interior of North America.

179. **Biatora rufonigra** Tuck.

On rocks, frequent. Grand Portage (Mt. Josephine), June 19, 1897, no. 37. Grand Portage island, June 21, 1897, no. 64. South Fowl lake, June 26, 1897, no. 193. Misquah hills, July 5, 1897, no. 456. Snowbank lake area, July 21, 1897, no. 859.

180. **Biatora coarctata** (Sm., Nyl.) Tuck.

On rocks, rare. Beaver Bay, July 13, 1897, no. 709.

Not previously reported from Minnesota.

181. **Biatora viridescens** (Schrad.) Fr.

On old wood, common locally. Misquah hills, July 3, 1897, no. 414.

Snowbank lake area, July 20, 1897, no. 846.

Not previously reported from Minnesota, and new to the interior of North America.

182. **Biatora vernalis** (L.) Fr.

On old wood, mosses and trees, frequent. Grand Portage island, June 21, 1897, no. 61, and June 23, 1897, no. 149. Gunflint, June 30, 1897, no. 262.

Not previously reported from Minnesota.

183. **Biatora sanguineoatra** (FR.) TUCK.

On earth common. Grand Portage island, June 19, 1897, no. 21 and 28. Grand Portage, June 24, 1897, no. 181. Gunflint, June 30, 1897, no. 269, and July 1, 1897, no. 359. Misquah hills, July 5, 1897, no. 413. Tofte (Carlton peak), July 10, 1897, no. 578. Snowbank lake area, July 22, 1897, no. 884.

Not previously reported from Minnesota.

184. **Biatora turgidula** (FR.) NYL.

On old wood, rare. Grand Portage island, June 18, 1897, no. 14.

Not previously reported from Minnesota.

185. **Biatora leucophæa** (FLOERK).

On rocks, infrequent. Grand Portage, June 23, 1897, no. 139, and June 24, 1897, no. 187. Gunflint, July 1, 1897, no. 306.

Not previously reported from Minnesota.

186. **Biatora leucophæa** FLOERK var. **griseoatra** KOERB.

On rocks, rare. Grand Portage, June 24, 1897, no. 186.

Not previously reported from Minnesota and new south of Arctic America.

187. **Biatora uliginosa** (SCHRAD.) FR.

On earth, abundant near Disappointment lake. Beaver Bay, July 13, 1897, no. 708. Snowbank lake area, July 24, 1897, no. 944. Ely, July 28, 1897, no. 997.

Not previously reported from Minnesota.

188. **Biatora sphæroides** (DICKS.) TUCK.

On old wood, rare. Snowbank lake area, July 24, 1897, no. 944a.

Not previously reported from Minnesota.

189. **Biatora glauconigrans** TUCK.

On trees, rare. Gunflint, July 1, 1897, no. 398.

Not previously reported from Minnesota and new west of New England.

190. **Biatora arthropurpurea** (MASS.) HEPP.

On trees, rare. Grand Portage island, June 21, 1897, no. 56. Snowbank lake area, July 22, 1897, no. 811. Ely, July 28, 1897, no. 1007.

191. **Biatora oxyspora** (TUL.) NYL.

On *Parmelia colpodes*, rare. Misquah hills, July 3, 1897, no. 416.

Not previously reported from Minnesota and new to the interior of North America.

192. **Biatora lucida** (ACH.) FR.

On damp rocks, rare. Grand Portage, June 23, 1887, no. 183.

Not previously reported from Minnesota and new to the interior of North America.

193. **Biatora myriocarpoides** (NYL.) TUCK.

On old wood, frequent locally. Beaver Bay, July 13, 1897, no. 673. Apothecia larger than usual.

194. **Biatora flavidolivens** TUCK.

On old wood, frequent locally. Rose lake, June 28, 1897, no. 214. Misquah hills, July 5, 1897, no. 504.

Not previously reported from Minnesota and new west of New England.

195. **Biatora hypnophila** (TURN.) TUCK.

On trees, rare. Gunflint, June 30, 1897, no. 273. Snowbank lake area, July 26, 1897, no. 956.

196. **Biatora nægelii** HEPP.

On old wood, rare. Beaver Bay, July 13, 1897, no. 715. Not previously reported from Minnesota and new west of New England.

197. **Biatora rubella** (EHRH.) RABENH.

On trees, rare or infrequent. Tofte (Carlton peak), July 10, 1897, no. 546. Beaver Bay, July 13, 1897, no. 640. Snowbank lake area, July 19, 1897, no. 812, July 21, 1897, no. 872, and July 24, 1897, no. 906. Ely, July 28, 1897, no. 1021.

198. **Biatora fuscorubella** (HOFFM.) TUCK.

On trees, infrequent. Snowbank lake area, July 17, 1897, no. 816, and July 21, 1897, no. 861.

199. **Biatora schweinitzii** FR.

On cedars, rare. Misquah hills, July 5, 1897, no. 493.

Not previously reported from Minnesota.

200. **Biatora incompta** (BORR.) HEPP.

On trees, probably common locally. Rose lake, June 28, 1897, no. 222. Gunflint, July 1, 1897, no. 335.

Not previously reported from Minnesota.

201. **Biatora muscorum** (Sw.) Tuck.

On trees with moss, rare. Snowbank lake area, July 26, 1897, no. 963.

202. **Heterothecium sanguinarium** (L.) Flot.

On old wood and occasionally on trees or rocks, common except in last region. Gunflint, July 1, 1897, nos. 318 and 319. Misquah hills, July 3, 1897, nos. 409 and 415, and July 5, 1897, nos. 492a and 498. Tofte (Carlton peak), July 10, 1897, no. 581. Beaver Bay, July 15, 1897, no. 695. Two Harbors, July 17, 1897, no. 796. Snowbank lake area, July 19, 1897, no. 810.

Not previously reported from Minnesota and new to the interior of North America.

203. **Heterothecium sanguinarium** (L.) Flot. var. **affine** Tuck.

On wood, rare. Rose lake, June 28, 1897, no. 222a.

Not previously reported from Minnesota and new to the interior of North America.

204. **Lecidea lactea** Fl.

On rocks along lake Superior, common especially north. Grand Portage island, June 21, 1897, no. 76, and June 23, 1897, no. 136. Grand Portage, June 23, 1897, no. 182. Tofte, July 12, 1897, no. 652. Palisades, July 15, 1897, no. 751.

Not previously reported from Minnesota and new to the interior of North America.

205. **Lecidea crustulata** Ach.

On rocks, rare. Grand Portage island, June 23, 1897, no. 137.

Not previously reported from Minnesota and known elsewhere in North America only from Labrador by Eckfeldt and Arnold.

206. **Lecidea lapicida** Fr.

On rocks, probably common locally. Misquah hills, July 5, 1897, no. 448.

Not previously reported from Minnesota and new to the interior of North America.

207. **Lecidea lapicida** Fr. var. **oxydata** Fr.

On rocks, rare. Grand Portage, June 24, 1897, no. 174.

Not previously reported from Minnesota and new to the interior of North America.

208. **Lecidea speirea** Nyl.

On rocks along lake shore, rare. Grand Portage island, June 23, 1897, no. 110.

Not previously reported from Minnesota.

209. **Lecidea albocærulescens** (Wulf.) Schaer.

On rocks, rare. Misquah hills, July 5, 1897, no. 484.

210. **Lecidea platycarpa** Ach.

On rocks, rare. Misquah hills, July 5, 1897, no. 474.

Not previously reported from Minnesota.

211. **Lecidea enteroleuca** Fr.

On trees and rocks, common. Grand Portage island, June 21, 1897, nos. 59b and 60, and June 23, 1897, no. 111. Grand Portage, June 23, 1897, no. 148. English Portage, June 26, 1897, no. 191. Misquah hills, July 5, 1897, no. 492. Beaver Bay, July 13, 1897, no. 700. Snowbank lake area, July 24, 1897, no. 909.

212. **Lecidea enteroleuca** Fr. var. **achrista** Sommerf.

On trees, infrequent. Grand Portage island, June 21, 1897, no. 59a. Grand Portage, June 23, 1897, no. 97.

Not previously reported from Minnesota.

213. **Lecidea melancheima** Tuck.

On old wood, rare. Gunflint, July 2, 1897, no. 390. Misquah hills, July 5, 1897, no. 454. Snowbank lake area, July 20, 1897, no. 835.

Not previously reported from Minnesota.

214. **Lecidea cyrtidia** Tuck.

On pebbles, rare, thallus reduced and hence the black hypothallus prominent. Snowbank lake area, July 27, 1897, no. 969.

Not previously reported from Minnesota.

215. **Lecidea acclinis** Flot.

On cedars, rare. Gunflint, July 1, 1897, no. 353.

Not previously reported from Minnesota.

216. **Buellia alboatra** (Hoffm.) Th. Fr.

On rocks, rare.

Grand Portage, June 23, 1897, no. 99.

Not previously reported from Minnesota.

217. **Buellia parasema** (Ach.) Th. Fr.

On trees, common. Ely specimen having spores reaching $\frac{18-30}{7-11}$ mic. Grand Portage island, June 16, 1897, no. 4, and

June 21, 1897, no. 65. South Fowl lake, June 26, 1897, no. 196. Gunflint, July 1, 1897, nos. 311 and 312. Misquah hills, July 5, 1897, no. 480. Beaver Bay, July 15, 1897, no. 676. Snowbank lake area, July 19, 1897, nos. 811a, 813 and 817. Ely, July 28, 1897, no. 989a.

218. **Buellia parasema** (ACH.) TH. FR. var. **triphragmia** NYL.

On trees, infrequent. Gunflint, June 30, 1897, nos. 255 and 278. Tofte, July 10, 1897, no. 613.

Not previously reported from Minnesota.

219. **Buellia dialyta** (NYL.) TUCK.

On pines, rare. Two Harbors, July 17, 1897, no. 792.

Not previously reported from Minnesota, and new to the interior of North America.

220. **Buellia myriocarpa** (DC.) MUDD.

On old wood, abundant locally. Beaver Bay, July 14, 1897, no. 716a.

221. **Buellia myriocarpa** (DC.) MUDD. var. **polyspora** WILLEY.

On trees, rare. Ely, July 28, 1897, no. 1011.

222. **Buellia petræa** (FLOT., KOERB.) TUCK.

On rocks, common or abundant. Grand Portage island, June 17, 1897, no. 5. Gunflint, June 30, 1897, nos. 281, 283 and 291. Misquah hills, July 5, 1897, no. 470. Beaver Bay, July 15, 1897, no. 779. Ely, July 28, 1897, no. 989.

223. **Buellia petræa** (FLOT., KOERB.) TUCK. var. **grandis** FLOERK.

On rocks, rare. Gunflint, June 30, 1897, no. 293, and July 1, 1897, no. 304.

224. **Buellia petræa** (FLOT., KOERB.) TUCK. var. **montagnæi** TUCK.

On rocks, common or abundant. Grand Portage (Mt. Josephine), June 18, 1897, no. 42. Gunflint, July 2, 1897, no. 379. Misquah hills, July 5, 1897, no. 467. Beaver Bay, July 13, 1897, no. 662. Palisades, July 15, 1897, no. 749. Snowbank lake area, July 20, 1897, no. 834.

225. **Buellia geographica** (L.) TUCK.

On rocks, rare and approaching var. *lecanorina* Flœrk Gunflint, June 30, 1897, no. 303. Palisades, July 15, 1897, no. 743.

Not previously reported from Minnesota, and new to the interior of North America.

226. **Buellia parmeliarum** (SOMMERF.) TUCK.

On *Parmelia borreri*, rare. Snowbank lake area, July 22, 1897, no. 885.

Not previously reported from Minnesota.

227. **Opegrapha varia** (PERS.) FR.

On trees, common on cedars except along lake Superior. Gunflint, July 1, 1897, no. 334. Misquah hills, July 5, 1897, no. 502. Tofte (Carlton peak), July 10, 1897, no. 593. Snowbank lake area, July 21, 1897, no. 857.

228. **Opegrapha varia** (PERS.) TUCK. FR. var. **notha** ACH.

On cedars, locally abundant. Rose lake, June 28, 1897, no. 220.

Not previously reported from Minnesota.

229. **Graphis scripta** (L.) ACH.

On trees, frequent or common. Grand Portage island, June 21, 1897, no. 66. Gunflint, July 1, 1897, nos. 314 and 317. Tofte (Carlton peak), July 10, 1897, no. 576. Beaver Bay, July 15, 1897, no. 716. Snowbank lake area, July 21, 1897, no. 858.

230. **Graphis scripta** (L.) ACH. var. **recta** (HUMB.) NYL.

On birch trees, infrequent. Grand Portage, June 24, 1897, no. 189. Misquah hills, July 3, 1897, no. 405. Tofte, July 12, 1897, no. 650. Snowbank lake area, July 23, 1897, no. 897.

231. **Graphis scripta** (L.) ACH. var. **limitata** ACH.

On trees, very rare. Resembles *G. dendritica* externally as to apothecia. Misquah hills, July 5, 1897, no. 451.

Not previously reported from Minnesota.

232. **Arthonia dispersa** (SCHRAD.) NYL.

On *Acer spicatum*, abundant. Grand Portage, June 23, 1897, no. 86. Tofte (Carlton peak), July 10, 1897, no. 590. Beaver Bay, July 13, 1897, no. 714. Snowbank lake area, July 20, 1897, no. 845. Ely, July 28, 1897, no. 979.

Not previously reported from Minnesota.

233. **Arthonia radiata** (PERS.) TH. FR.

On trees in low places, common. Grand Portage island, June 23, 1897, no. 123. Rose lake, June 28, 1897, no. 219. Gunflint, July 1, 1897, no. 315, and July 2, 1897, no. 388. Tofte (Carlton peak), July 10, 1897, no. 584, Beaver Bay, July 15, 1897, no. 785. Snowbank lake area, July 20, 1897, no. 838. Ely, July 28, 1897, no. 1013.

234. **Arthonia punctiformis** Ach.

On trees, locally common. Gunflint, June 30, 1897, no. 277. Misquah hills, July 3, 1897, no. 407.

235. **Arthonia patellulata** Nyl.

On trees, rare. Gunflint, June 30, 1897, no. 254.

Not previously reported from Minnesota.

236. **Calicium trichiale** Ach.

On trees, common locally. Rose lake, June 28, 1897, no. 230. Beaver Bay, July 15, 1897, no. 696. Snowbank lake area, July 19, 1897, no. 818.

Not previously reported from Minnesota, and new to the interior of North America.

237. **Calicium trichiale** Ach. var. **stemoneum** Nyl.

On pine, common. Ely, July 28, 1897, no. 992.

Not previously reported from Minnesota, and new to the interior of North America.

238. **Calicium brunneolum** Ach.

On decorticated wood, common locally. Two Harbors, July 17, 1897, no. 800. Snowbank lake area, July 12, 1897, no. 860. Ely, July 26, 1897, no. 1000.

Not previously reported from Minnesota, and new to the interior of North America.

239. **Calicium chrysocephalum** (Turn.) Ach.

On trees, frequent. Misquah hills, July 5, 1897, no. 447. Two Harbors, July 17, 1897, no. 788. Snowbank lake area, July 22, 1897, no. 882. Ely, July 28, 1897, no. 1003.

Not previously reported from Minnesota, and new to the interior of North America.

240. **Calicium chrysocephalum** (Turn.) Ach. var. **filare** Sch.

On cedars, rare. Tofte, July 12, 1897, no. 647.

Not previously reported from Minnesota. Variety apparently new to North America.

241. **Calicium parietinum** Ach.

On decorticated wood, common. Grand Portage island, June 17, 1897, no. 3. Gunflint, July 2, 1897, no. 382. Misquah hills, July 3, 1897, no. 408.

Not previously reported from Minnesota.

242. **Calicium quercinum** Pers.

On dead wood, infrequent. Rose lake, June 28, 1897, no. 229. Tofte (Carlton peak), July 10, 1897, no 583.

Not previously reported from Minnesota.

243. **Calicium hyprellum** Ach. var. **viride** Nyl.

On trees, rare. Misquah hills, July 5, 1897, no. 476. Snowbank lake area, July 21, 1897, no. 877, and July 22, 1897, no. 893. Ely, July 28, 1897, no. 1015.

Not previously reported from Minnesota. Variety new to North America. Stipes sometimes very short.

244. **Calicium turbinatum** Pers.

On *Pertusaria communis*, rare. Beaver Bay, July 13, 1897, no. 664a. Snowbank lake area, July 21, 1897, no. 866.

Not previously reported from Minnesota.

245. **Coniocybe pallida** (Pers.) Fr.

On *Fraxinus*, rare. Snowbank lake area, July 19, 1897, no. 831.

Not previously reported from Minnesota.

246. **Endocarpon miniatum** (L.) Schaer.

On rocks, along shore of lake Superior, very rare. Grand Portage island, June 21, 1897, no. 80.

247. **Endocarpon miniatum** (L.) Schaer. var. **complicatum** Schaer.

On rocks, frequently 1000 feet above water level, frequent. Grand Portage (Mt. Josephine), June 19, 1897, no. 38. Grand Portage island, June 23, 1897, no 102. Misquah hills, July 5, 1897, no. 445.

248. **Endocarpon fluviatile** DC.

On rocks frequently inundated, common. Rose lake, June 28, 1897, no. 211. Gunflint, July 1, 1897, no. 327. Misquah hills, July 7, 1897, no. 512. Snowbank lake area, July 21, 1897, no. 878.

249. **Thelocarpon prasinellum** Nyl.

On rocks, rare. Grand Portage (Mt. Josephine), June 22, 1897, no. 90.

The plant agrees here and not with saxicoline species, European or American.

250. **Staurothele umbrina** (Wahl.) Tuck.

Wet rocks, common. Misquah hills, July 5, 1897, nos.

462, 519 and 520. Snowbank lake area, July 26, 1897, no. 957.

Not previously reported from Minnesota.

251. **Staurothele drummondii** Tuck.

On rocks along the shore, frequent locally. Grand Portage island, June 21, 1897, no. 72.

Not previously reported from Minnesota and new to the interior of North America.

252. **Verrucaria nigrescens** Pers.

On rocks, rare. Grand Portage, June 24, 1897, no. 184.

253. **Verrucaria epigæa** (Pers.) Ach.

On earth, rare. Snowbank lake area, July 26, 1897, no. 944.

Not previously reported from Minnesota.

254. **Sagedia oxyspora** (Nyl.) Tuck.

On birch, rare. Beaver Bay, July 13, 1897, no. 697.

Not previously reported from Minnesota and new to the interior of North America.

255. **Pyrenula punctiformis** (Ach.) Naeg. var. **fallax** Nyl.

On trees, common. Gunflint, June 30, 1897, no. 276. Misquah hills, July 5, 1897, no. 503. Snowbank lake area, July 21, 1897, no. 871, and July 26, 1897, no. 950.

Not previously reported from Minnesota.

256. **Pyrenula leucoplaca** (Wallr.) Krb.

On trees, common to west of region. Between Rose and Rove lakes, June 27, 1897, no. 209. Gunflint, July 2, 1897, no. 391. Misquah hills, July 5, 1897, nos. 499 and 507. Snowbank lake area, July 19, 1897, no. 828, July 20, 1897, no. 852, and July 26, 1897, nos. 955, 958 and 959. Ely, July 28, 1897, nos. 1009 and 1019.

257. **Pyrenula cinerella** (Flot.) Tuck.

On birch, common. Grand Portage island, June 21, 1897, no. 56.

The only American specimens seen by me which show the spores as large as those of the European plant. Spores measured 12–18 by 6–9 mic. Spore measurements for the species in America are more commonly 12–17 by 5–7 mic., my Iowa specimens giving 12–16 by 6–7 mic., and T. A. William's from Nebraska, 15–17 by 5½–7 mic.

Not previously reported from Minnesota.

258. **Pyrenula cinerella** (FLOT.) TUCK. var. **quadriloculata,** *var. nov.*

Spores 12–15 by 5–6½ mic., passing from 2 and occasionally 3-celled to a much more common 4-celled condition. The apothecia somewhat below normal size for the species. *Pyrenula punctiformis* Ach., Naeg. var. *fallax* Nyl., quite commonly occurs with the species and variety, as it does with the latter in the present instance and with the former both in Minnesota and Iowa.

On birch, probably common locally. Grand Portage island, June 24, 1897, no. 85.

XIX. CONTRIBUTIONS TO A KNOWLEDGE OF THE LICHENS OF MINNESOTA.—V. LICHENS OF THE MINNESOTA VALLEY AND SOUTHWESTERN MINNESOTA.

BRUCE FINK.

CONSIDERATIONS OF DISTRIBUTION AND HABITAT.

The area considered in this paper was selected with a view to obtaining as complete a knowledge as possible of the lichen flora of the Minnesota river valley and of that of southwestern Minnesota in general.

The upper portion of the valley near Minneapolis would, of course, give a flora essentially like that of Minneapolis and vicinity already studied. Hence, for the month's field work, it was thought best to begin operations at a locality a considerable distance from Minneapolis. As an initial place, Mankato, about 60 miles from Minneapolis, was selected. The location of this city is also advantageous in that it lies nearly midway between the Minneapolis and the northeastern Iowa areas compared carefully in the second paper of this series, thus forming a connecting link between the two areas previously studied. After a careful study of the lichens of the Mankato area both to gain a knowledge of the lichen flora of the region and for the sake of relationships with the areas indicated above, New Ulm was next selected as an area of special interest because of the exposures of Cretaceous sandstone and the most southeastward exposures of quartzite rocks in the valley. At New Ulm only these two rock formations were studied, as time spent on other substrata present would only be repaid for most part by a repetition of the species found upon the same substrata at Mankato, only 30 miles distant. Three days were next spent at Redwood Falls, Morton and North Redwood with a view to securing rare species and noting the southeastern extension of certain species in the valley. From here I proceeded to Granite Falls.

This being the most northwestern area reached in the survey, its lichen flora was studied carefully. The final task was to study the lichen flora of the pipestone and the Sioux quartzite at Pipestone.

A brief statement as to substrata is next in order. About Mankato trees abound, and three kinds of rock—limestone, sandstone and bowlders—are plentiful. I found only the two interesting substrata mentioned above at New Ulm. Trees and bowlders were abundant, but were not studied for the reason already stated. At Redwood Falls, Morton and North Redwood, granite trees and earth were examined for species especially rare or interesting. The great masses of granite, supposed to have been exposed since the close of the glacial age, formed the most interesting substratum at Granite Falls. This is also the most northwestern area in the valley where trees occur in any considerable numbers. The calcareous drift pebbles and calcareous earth proved also very interesting here. The two substrata examined at Pipestone have been mentioned. I need to add only one statement more to make the analysis of substrata complete enough for the present purpose. This is that earth was examined everywhere and furnished much of interest, as will appear later.

The following rare lichens were found only at Redwood Falls, Morton or North Redwood: *Peltigera canina* (L.) Hoffm. var. *spongiosa* Tuck. and *Stereocaulon paschale* (L.) Fr. Also the area including the above places forms the most southeastern known extension of the following lichens in the valley: *Parmelia olivacea* (L.) Ach. var. *prolixa* Ach.; *Pannaria microphylla* (Sw.) Delis; *Omphalaria phyllisca* (Wahl.) Tuck.; *Lecanora frustulosa* (Dicks.) Mass., and *Buellia pullata* Tuck. With this much in hasty review I shall pass to localities more thoroughly studied. However, I may add here better than elsewhere in my paper that *Rinodina orcina* (Ach.) Mass. and *Lecanora xanthophana* Nyl. are here and elsewhere in the valley far more abundant than I have ever found them in other regions.

In attempting a general comparative study of distribution in the valley the places that present questions of greatest interest are the vicinities of Mankato and Granite Falls, where all sorts of substrata were examined. The two areas were about equally well studied, though the former, because of the greater number and less accessibility of rocky substrata, required more time. The former area furnished 151 species and varieties and the latter 124. A brief analysis of the causes of the advantage in favor of the former region can be best made by a consideration of the subjoined table, giving the various substrata for both localities with the number of lichens most commonly found on each.

	Numbers for Mankato.	For Granite Falls.
Trees	60	41
Rocks	55	54
Earth	22	17
Dead wood	14	12

A complete analysis introducing per cents as was made in a former paper is not necessary since general likeness except for trees is apparent in the table. The difference in richness then is due mainly to absence of large areas of trees at Granite Falls. The slight differences in the other three items in the table is doubtless due to difference in moisture, the precipitation being 30.53 inches annually at Mankato for three years for which I could get data and 21.83 inches annually at Granite Falls for five years for which data were obtained. Difference in moisture doubtless also accounts in small measure for the advantage of the Mankato area as to arboreal lichens.

As to rocky substrata favorable to lichen growth little can be definitely given by way of comparison. As to kinds of rocks Mankato has an advantage in having the sandstone which is wanting at Granite Falls, and also in the great masses of limestone which are replaced at Granite Falls only by the calcareous drift pebbles and a few bowlders. Yet these two advantages are probably quite overcome by the great masses of exposed granite at Granite Falls, not replaced at Mankato in any way, since granitic bowlders are equally abundant in both places.

Comparing the Mankato vicinity with Minneapolis and with Fayette, Iowa, two areas compared in a former portion of these studies, we find that it has a much richer lichen flora than the former region which gave only 113 lichen forms and probably nearly as rich as the latter which gave 157 lichens which one could expect to find in a study of limited duration.

Minnesota has now furnished more lichens than any other state in the Mississippi Valley, having 351 species and varieties. Illinois with 249 lichens being next in order. Yet the fact that northeastern Iowa, a portion of a State not so thoroughly surveyed and only having 226 known lichens, has 26 lichens not yet found in Minnesota, shows that the study of Minnesota lichens is by no means yet approximately completed, since a large part of these 26 rare or obscure lichens found already within 50 miles of the state certainly exist within its borders in the southeastern portion, and other unstudied portions of the state may yet be expected to bring additions to the lichen flora in like proportion. A list of these 26 lichens could be added with habitats to aid in their discovery in southeastern Minnesota but an inspection of another paper* will give the names of them.

A study of the table above, giving habitats and number of species for each, by per cents, would give a somewhat larger per cent. of lithophytic lichen species for the two areas considered than a former study exhibited for the Minneapolis and Iowa localities and about the same per cent. as the lake Superior region. I subjoin, arranged according to habitat, a list of the 41 lichens added to the state in this paper. From the list it will be seen that more than half of these species are most common on rocks, and that the great Archean and Algonkian masses exposed throughout the upper valley alone produced one-third of them. For convenience of reference to the above statements I shall now add the table, placing rock species first, and then follow the list with further discussion.

New to Minnesota on Archean or Algonkian rocks.

Ramalina polymorpha (ACH.) TUCK.
Parmelia saxatilis (L.) FR. var. **panniformis** (ACH.) SCHAER.
Pyrenopsis phæococca TUCK.
Pyrenopsis melambola TUCK.
Omphalaria phyllisca (WAHL.) TUCK.
Leptogium pulchellum (ACH.) NYL.
Lecanora sp.
Lecanora subfusca (L.) ACH. var. **allophana** ACH.
Lecanora cinerea (PERS.) NYL. var. **cinereoalba** var. nov.
Rinodina sophodes (ACH.) NYL. var. **tephraspis** TUCK.

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* Fink, B. Review of Lichenological Studies in the Upper Mississippi Valley, with suggestions for future investigations. In list to be published in *Memoirs of the Torrey Botanical Club.*

Rinodina lecanorina MASS.
Urceolaria actinostoma PERS.
Buellia pullata TUCK.

New to Minnesota on limestone.

Omphalaria kansana TUCK.
Omphalaria pulvinata NYL.
Collema plicatile SCHAER.
Collema pustulatum ACH.
Lecanora bookii (FR.) TH. FR.
Rinodina bischoffii (HEPP.) KOERB.
Buellia alboatra (HOFFM.) TH. FR. var. **saxicola** FR.
Staurothele diffractella (NYL.) TUCK.

New to Minnesota on wood.

Placodium ferrugineum (HUDS.) HEPP.
Placodium ferrugineum (HUDS.) HEPP. var. **pollinii** TUCK.
Cladonia cristatella TUCK. var. **paludicola** TUCK.
Biatora flexuosa FR.
Biatora suffusa FR.
Buellia turgescens (NYL.) TUCK.
Opegrapha varia (PERS.) FR. var. **pulicaris** FR.
Arthonia sp.
Endocarpon arboreum SCHWEIN.
Pyrenula gemmata (ACH.) NAEG.
Pyrenula hyalospora NYL.
Pyrenula quinqueseptata (NYL.) TUCK.
Pyrenula glabrata (ACH.) MASS.
Pyrenula megalospora sp. nov.

New to Minnesota on earth.

Heppia despreauxii (MONT.) TUCK.
Heppia polyspora TUCK.
Collema tenax (SW.) ACH.
Biatora decipiens (EHRH.) FR.
Biatora decipiens (EHRH.) FR. var. **dealbata** AUCT.

The list of species new to the state shows a large number of *Pyrenulas*, the genus being unusually well represented in the valley, especially at Mankato. It will also be seen that the gelatinous lichens, the *Collemei*, are especially conspicuous in the genera *Pyrenopsis*, *Omphalaria*, *Collema* and *Leptogium*. This happens because part of the valley is more favorable for their development as to substrata and moisture than other studied portions of the state. The part of the studied portion of the valley most favorable for their development is the Mankato vicinity where most of the gelatinous lichens were found. The whole number of *Collemei* found in the valley is 17. Richness is apparent when we add that only four were found about Minneapolis, 11 in the lake Superior region and that only 16 are known in Iowa.

It may be added that a large proportion of the species added to the state flora are of special interest for various reasons. Thus the *Omphalarias* are not commonly collected; *Lecanora bookii* (Fr.) Th. Fr. is a difficult lichen to detect; the *Pyrenulas* are difficult to distinguish macroscopically and are therefore commonly overlooked; members of the genus *Pyrenopsis* are seldom reported; while *Urceolaria actinostoma* Pers., *Buellia pullata* Tuck. and *Heppia polyspora* Tuck. are very rare lichens. *Rinodina lecanorina* Mass. is reported for the first time from North America, and *Lecanora cervina* (Pers.) Nyl. var. *cinereoalba* var. nov. is interesting because new.

It may be noted in passing that the region shows some of the Arctic or sub-Arctic species found at Taylor's Falls and already discussed in a former paper. These are *Biatora rufonigra* Tuck., two forms of *Buellia petræa* (Flot., Koerb.) Tuck. and an *Ephebe*, though not the species reported from Taylors Falls. As in the Taylors Falls region the *Buellia* is the most common of these species being a crustaceous form well adapted to resist unfavorable conditions. The *Biatora* is next in frequency of occurrence and the *Ephebe*, a fruticulose form, was only seen once. So far as I was able to ascertain by careful search the foliaceous forms, *Umbilicaria* and *Nephroma*, found at Taylors Falls have not succeeded in persisting in the Minnesota valley. This failure of northern forms to persist so successfully may be accounted for perhaps in a very small degree by more southern position of the area now under consideration, but no doubt is due much more to climatic and edaphic factors which have allowed plant migrations to proceed northward more rapidly in the Minnesota valley than farther east in the state since the last retreat of the glaciers. This matter has been touched upon by Professor C. MacMillan.* It is interesting to note that the strictly crustaceous *Buellia* is the only one of the more northern forms found in the state which persists as far south as Pipestone. Indeed, its abundance here and records of occurrence elsewhere well southward in low altitudes since Tuckerman wrote lead to the suspicion that it may not be so strictly sub-Arctic in distribution as I have supposed. It may be added that the *Buellia* is the only one of these northern species persisting in the valley, which was found on bowlders at any considerable distance from the large masses of Archean and Algonkian rocks, which are supposed to have been exposed continuously since the close of the glacial epoch, and that it was only found once in very small quantity on a bowlder remote from these larger masses.

It has been my plan to introduce in each paper of the series some feature regarding distribution which could be especially well illustrated by the area under consideration. In the study of the Minnesota valley and southwestern Minnesota I was able to keep in mind a variety of ecologic factors and to preserve the data necessary for their solution. This I had previously done in part for several areas in Minnesota and Iowa so that in the present paper interesting and instructive comparisons can be made. Leaving other questions, then, thus briefly stated, I shall now pass to a consideration of the lichen formations of the region, causes of their peculiar make-up, and comparisons with similar formations within and outside the area under consideration.

Aside from the purely scientific interest of the analysis to follow, it has a practical bearing, in that knowledge of the relation between ecologic factors and distribution enables the collector to predict in the field about what species of lichens he may expect to find in a spot having a given set of environmental features. In the study species rarely found in the formations have not been considered when there appeared to be doubt as to whether they were collected on their usual substrata, and rarer varieties have been omitted when showing the same habitat as other forms of the species. It will be readily granted that the commoner forms which give character to the flora are the ones which should receive attention in such a study. In the analysis, especially as to amount of illumination and the roughness of ligneous substrata, it will be seen that lines can not be drawn very closely without entailing an amount of minutiæ which would be confusing and therefore unprofitable.

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* MacMillan, C., Observations on the Distribution of Plants Along the Shore at Lake of the Woods. Minn. Bot. Stud. 1 : 967. 1897.

With the above brief statement as to the main purpose of the present paper, I shall begin the consideration of lichen formations with the most distinct ones with which I am acquainted, viz., those of the Sioux quartzite at Pipestone. These formations are distinct because for most part removed from trees from which lichens commonly migrate to rocks nearby, producing tension lines and mixture of formations and because the few young trees found, though large enough to bear the foliaceous lichens which commonly migrate to the rocks, have apparently been isolated from larger areas of trees from the beginning of growth and scarcely bear a lichen of any kind. The rocky substratum is for the most part horizontal and exposed to the sun's rays. In a few places occur perpendicular rock exposures which are more or less shaded by trees, overhanging rocks or north exposure. A few ombrophytic lichens occupy these spots; but they are all strictly lithophytic species, none of them having, for the reason stated above, migrated from trees as we shall find to be the condition in a later analysis of other similar formations. Below I give first the lichen formation of the horizontal exposed rocks and second, that of the more or less shaded and damp rocks. *Lecanoras* predominate in the formations on exposed rocks, which may accordingly be named as follows:

Lecanora formation of the horizontal exposed quartzite (Pipestone).

Parmelia olivacea (L.) Ach. var. **prolixa** Ach., C.
Parmelia conspersa (Ehrh.) Ach., C.
Physcia tribacia (Ach.) Tuck., C.
Physcia cæsia (Hoffm.) Nyl.
Placodium elegans (Link.) DC., C.
Placodium vitellinum (Ehrh.) Naeg. and Hepp.
Lecanora rubina (Vill.) Ach., C.
Lecanora rubina (Vill.) Ach. var. **heteromorpha** Ach., C.
Lecanora cinerea (L.) Sommerf., C.
Lecanora xanthophana Nyl., C.

Rinodina oreina (ACH.) MASS., C.

Buellia spuria (SCHAER.) ARN., C.

Buellia pullata TUCK., C.

Buellia petræa (FLOT., KOERB.) TUCK. var. **montagnæi** TUCK., C.

Endocarpon miniatum (L.) SCHAER. var. **complicatum** SCHAER., C.

The formation on shaded rocks may be designated the *Staurothele formation*, after the prevailing genus.

Staurothele formation of shaded or damp quartzite (Pipestone).

Endocarpon miniatum (L.) SCHAER.

Staurothele umbrina (WAHL.) TUCK., C.

Staurothele drummondii TUCK., C.

The lichen formations of the pipestone lying beside the quartzite were studied to ascertain to what extent the difference in chemical composition and hardness of the rocks would influence the distribution of lichens, other ecologic factors being identical. In the above table I have indicated species common to quartzite and pipestone by (C.), and the table shows that only three lichens were detected on the quartzite and not on the pipestone. The following three, all growing in exposed places, were found on the latter and not on the former.

Placodium cinnabarrinum (ACH.) AUZ.

Placodium cerinum (HEDW.) NAEG. and HEPP. var. **sideritis** TUCK.

Lecanora muralis (SCHREB.) SCHAER. var. **saxicola** SCHAER.

It is worthy of note that the differences are specific and that the formations are identical generically. The appearance of a certain plant in a particular set of ecological conditions is too complicated a matter for exact explanation in many instances, and I can offer no explanation as to why the few plants occur on one kind of rock and not on the other. Possibly the specific acid secreted by a particular species acts more readily on one kind of rock than on the other, but more probably the cause is other than this. Nor do I suppose that I have found, here or in other formations to be considered below, all the lichens growing under a particular set of conditions. Yet the common ones which give character to the various formations were doubtless all detected here as elsewhere, and the fact that 15 of 18 were found on each kind of rock demonstrates that difference in composition of rock in this instance has produced little, if any difference in lichen flora. A similar study of lichen formations on large rock areas of greater difference in composition as granite and limestone lying adjacent would be of special interest.

To complete the lichen formations of the area, the earth-lichen formation must be considered. This formation and similar ones elsewhere may be called the *Endocarpon hepaticum formations of exposed earth* from a plant which is found in such formations in all parts of the state except the lake Superior region.

Endocarpon hepaticum formation of exposed earth (Pipestone).

Urceolaria scruposa (L.) Nyl.
Cladonia pyxidata (L.) Fr.
Cladonia fimbriata (L.) Fr.
Cladonia fimbriata (L.) Fr. var. **tubæformis** Fr.
Biatora muscorum (Sw.) Tuck.
Endocarpon hepaticum Ach.
Endocarpon pusillum Hedw. var. **garovaglii** Kph.

The region is a comparatively dry one because of small precipitation of moisture, since the rocks lie high where there is little or no standing water to give moisture and because there are few trees to give shade. The lichen formations are accordingly rather poor in species, as will appear in comparisons to follow an analysis of similar formations.

The rocky surfaces at Granite Falls present a much more complex set of conditions than those just considered, and yet, for my purpose, they may be classified, like the latter, into exposed surfaces, usually horizontal, and shaded surfaces, usually more or less nearly perpendicular. I shall now record these formations in the same order as in the last series; but after each shall compare it with the corresponding formation at Pipestone, giving, as far as possible, the probable cause of differences.

Lecanora formation of exposed (usually horizontal) granite (Granite Falls).

Parmelia olivacea (L.) Ach. var. **prolixa** Ach.
Parmelia conspersa (Ehrh.) Ach.

Physcia stellaris (L.) TUCK. var. **apiola** NYL., A.

Physcia cæsia (HOFFM.) NYL.

Placodium elegans (LINK.) DC.

Placodium murorum (HOFFM.) DC., A.

Placodium cinnabarrinum (ACH.) AUZ.

Placodium cerinum (HEDW.) NAEG. and HEPP. var. **sideritis** TUCK.

Placodium vitellinum (EHRH.) NAEG. and HEPP.

Lecanora rubina (VILL.) ACH.

Lecanora rubina (VILL.) ACH. var. **heteromorpha** ACH.

Lecanora muralis (SCHREB.) SCHAER., A.

Lecanora muralis (SCHREB.) SCHAER. var. **saxicola** SCHAER.

Lecanora frustulosa (DICKS.) MASS., A.

Lecanora subfusca (L.) ACH. var. **allophana** ACH., A.

Lecanora subfusca (L.) ACH. var. **coilocarpa** ACH., A.

Lecanora hageni ACH., A.

Lecanora cinerea (L.) SOMMERF.

Lecanora calcarea (L.) SOMMERF. var. **contorta** FR., A.

Lecanora xanthophana NYL.

Lecanora cervina (PERS.) NYL. var. **cinereoalba** var. nov., A.

Lecanora fuscata (SCHRAD.) TH. FR., A.

Rinodina oreina (ACH.) MASS.

Rinodina sophodes (ACH.) NYL., A.

Rinodina lecanorina MASS., A.

Urceolaria actinostoma PERS., A.

Biatora rufonigra TUCK., A.

Buellia spuria (SCHAER.) ARN.

Buellia pullata TUCK.

Buellia petræa (FLOT., KOERB.) TUCK.

Endocarpon miniatum (L.) SCHAER., var. **complicatum** SCHAER.

Comparing this lichen formation with the similar ones of the Sioux quartzite and the pipestone, we find it to contain all lichens found on the two except *Physcia tribacia* (Ach.) Tuck. and to contain fourteen not found on them, which I have marked as additions (A). The absence of the one species from the Granite Falls formation is doubtless an accident in plant distribution whose explanation would be very difficult or impossible to trace; but it is quite remarkable that with this exception all the plants found in the two formations sixty miles away should occur in this lichen formation also, especially since there could have been no rocky connection between the two areas since glacial times. It is not strange that the exposed granite lichen formation at Granite Falls should be a much richer one than the two exposed formations at Pipestone combined; for it is a much larger area, is connected with a limestone lichen formation and an epiphytic, and a number of swamps and ponds furnish moisture along the borders. Indeed the presence of ten of the fourteen additions may be more or less satisfactorily explained. These I shall proceed to consider *seriatim*.

Physcia stellaris (L.) TUCK., var. **apiola** TUCK.—a lithophytic variety of a species common on adjacent trees.

Lecanora frustulosa (DICKS.) MASS.—a northern lichen not extending so far south as Pipestone.

Lecanora subfusca (L.) ACH., var. **alliophana** ACH.—a variety of a species common on trees near by.

Lecanora subfusca (L.) ACH., var. **coilocarpa** ACH.—as the last above.

Lecanora cervina (PERS.) NYL., var. **cinereoalba** var. nov.—has not been seen outside the Minnesota valley.

Lecanora calcarea (L.) SOMMERF., var. **contorta** FR.—a lichen migrating from the limestone near by.

Rinodina sophodes (ACH.) NYL.—found on trees of the region and perhaps migrating from them.

Rinodina lecanorina MASS.—a very rare plant which, therefore, very probably does not exist at Pipestone or was overlooked.

Urceolaria actinostoma PERS.—as the last above.

Biatora rufonigra TUCK.—a northern form not extending so far south as Pipestone.

Though somewhat confusing another similar lichen formation must be introduced here for comparison as follows:

Lecanora formation of exposed quartzite (New Ulm).

Parmelia conspersa (EHRH.) ACH., CTS.

Physcia cæsia (HOFFM.) NYL., CTS.

Placodium cerinum (HEDW.) NAEG. and HEPP. var. **sideritis** Tuck., CT.

Placodium vitellinum (EHRH.) NAEG. and HEPP., CTS.

Lecanora rubina (VILL.) ACH., CTS.

Lecanora rubina (VILL.) ACH. var. **heteromorpha** ACH., CS.

Lecanora subfusca (L.) ACH., S.

Lecanora varia (EHRH.) NYL., AS.

Lecanora cinerea (L.) SOMMERF., CTS.

Lecanora xanthophana NYL., C.

Rinodina oreina (ACH.) MASS., C.

Rinodina sophodes (ACH.) NYL.

Biatora rufonigra TUCK., T.

Biatora myriocarpoides (NYL.) TUCK., A.

Buellia spuria (SCHAER.) ARN., CT.

Buellia petræa (FLOT., KOERB.) TUCK., CTS.

Endocarpon miniatum (L.) SCHAER. var. **complicatum** SCHAER., C.

Comparing the above lichen formation with the similar ones at Pipestone and Granite Falls we find it to contain only two species which are additions to the three at the two places just named. These I have marked (A). It is about as extensive an area as the two at Pipestone combined, has about the same number of lichens as both and has 12 species (marked C) which are common to all the exposed rock lichen formations in the area considered in this paper. In general these 12 species may be regarded as the most constant of the exposed Archean and Algonkian rock lichen formations of southwestern Minnesota. As we multiply areas of comparison and especially as we introduce those at a greater distance the number of common floral elements very naturally decreases. Thus considering the similar formation at Taylors Falls, we find only 8 species (marked T) common to it and all the similar ones previously considered, and passing to the corresponding formation at Gunflint in the lake Superior region, the number found in all these similar formations in widely separated areas of the state is found to be only 6 (marked S). These 6 species may be looked for with considerable certainty wherever such lichen formations are well developed in the state. Other elements will vary according to relation to other adjacent formations, position northward or southward and in some instances eastward or westward in the state and to various ecologic factors which cannot be enumerated fully.

We may now turn to the lichen formation of shaded or damp rocks at Granite Falls. This includes some flat rock surfaces somewhat shaded or simply wet part of the time, as well as the perpendicular shaded surfaces. I shall divide the formation into three parts—species naturally belonging to the rocks, those which have probably migrated from the trees near at hand and those which have probably migrated from the earth. Here and in another formation we have a mixture of elements, hence the following name is proposed:

Mixed formation of shaded (or damp) granite (Granite Falls).

A. PROBABLY NATURALLY BELONGING TO THE ROCKS.

Ramalina polymorpha (ACH.) TUCK.
Ramalina calicaris (L.) FR. var. **farinacea** SCHAER.
Pannaria microphylla (SW.) DELIS.
Pannaria languinosa (ACH.) KOERB.
Omphalaria phyllisca (WAHL.) TUCK.
Collema furvum (ACH.) NYL.
Leptogium lacerum (SW.) FR.
Endocarpon muriatum (L.) SCHAER.
Staurothele umbrina (WAHL.) TUCK.
Staurothele diffractella (NYL.) TUCK.
Staurothele drummondii TUCK.

B. NEAR TREES AND PROBABLY MIGRATED FROM THEM.

Parmelia cetrata ACH.
Parmelia crinita ACH.
Parmelia borreri TURN.
Parmelia borreri TURN. var. **hypomela** TUCK.
Parmelia saxatilis (L.) FR.
Parmelia saxatilis (L.) FR. var. **sulcata** NYL.
Parmelia saxatilis (L.) FR. var. **panniformis** (ACH.) SCHAER.
Parmelia caperata (L.) ACH.
Physcia speciosa (WULF., ACH.) NYL.
Physcia pulverulenta (SCHREB.) NYL.
Physcia obscura (EHRH.) NYL.
Pyxine sorediata FR.
Leptogium myochroum (EHRH., SCHAER.) TUCK.

Placodium aurantiacum (LIGHTF.) NAEG and HEPP.
Biatora fuscorubella (HOFFM.) TUCK.

C. SPECIES WHICH HAVE PROBABLY MIGRATED FROM EARTH.

Peltigera rufescens (NECK.) HOFFM.
Peltigera canina (L.) HOFFM.

Of the three parts of the formation under consideration only the first can be compared with the similar formation at Pipestone, and we find besides the 3 species of the Pipestone formation, 8 additional forms as a result of greater areas studied, more moist conditions near the Minnesota river, and where abundant ponds and marshes situated near the rocks give moisture, and where trees are numerous in some parts of the area and increase the shade. I must add that presence of the *Ramalinas* here, and their absence from shaded rocks at Pipestone leads to the suspicion that they may have sprung from *Ramalina calicaris* (L.) Fr. of the region, migrating from trees to rocks and acquiring the varietal, and in one instance the specific characters as an adaptation to changed environment. The question is as to whether these lichens are sufficiently plastic to acquire such new characters since trees have grown in the valley in post-glacial time. I can only say that I believe that they may be, and that it is quite as likely that the two *Ramalinas* should be placed in the second division of the formation as in the first.

As to plants of the second portion of the formation, which I have designated as having probably migrated from trees, in some instances they are locally more abundant and luxuriant on the rocks than on trees. Hence a hasty consideration would lead to the conclusion that they have not migrated. But the luxuriant condition obtains on the rocks in *Parmelia borreri* Turn., a lichen seldom seen on rocks elsewhere, and many of these lichens grow on mossy rocks where lichens are commonly large. Also it is to be taken into account that these lichens are those usually found on large trees with rough bark. The larger trees were for most part destroyed years ago by man or fires, and these lichens, formerly common on trees, are preserved on rocks better than on the less permanent trees. Hence some of them are more common now on the rocks than on the trees, which are for most part second growth and not large. The third division, consisting of two *Peltigeras*, scarcely needs any special consideration.

I shall next consider the similar shaded rock formation at New Ulm, which may be divided into those lichens naturally belonging to the rocks and those probably migrating from trees.

Mixed lichen formation of shaded rocks (New Ulm).

A. NATURALLY BELONGING TO THE ROCKS.

Pannaria languinosa (ACH.) KOERB.

Collema flaccidum ACH.

Collema furvum (ACH.) NYL.

B. NEAR TREES AND PROBABLY MIGRATED FROM THEM.

Theloschistes lychneus (NYL.) TUCK., CTS.

Parmelia crinita ACH., CTS.

Parmelia borreri TURN., CTS.

Parmelia saxatilis (L.) FR., CTS.

Parmelia saxatilis (L.) FR. var. **panniformis** (ACH.) SCHAER., C.

Parmelia caperata (L.) ACH., CTS.

Physcia speciosa (WULF. ACH.) NYL., CTS.

Physcia pulverulenta(SCHREB.) NYL., CTS.

Physcia stellaris (L.) TUCK., TS.

Physcia obscura (EHRH.) NYL., CTS.

As to the shaded rock lichen formations of the region surveyed considering only plants naturally belonging to the rocks, there is not a single lichen that is common to all of them. *Pannaria languinosa* (Ach.) Koerb. is the most constant element of such formations, which as a whole might be named for this plant were it not quite as common in shaded limestone formations otherwise quite different from any of those on the rocks under consideration at present. Of the lichens of the shaded rock formation at New Ulm, which have probably migrated from trees, the nine marked common (C), may be taken as the ones most commonly occurring, as they were found also at Granite Falls in the similar formation. Those marked (T) all but one of the nine, occur in the similar formation at Taylors Falls. Other elements vary more with change in various ecologic factors. The similar partial formation was noted at Grand Portage, especially on the island, and adding those lichens (S) of it found in the corresponding ones considered above, subtracts none from the number of common species. Therefore, these eight lichens may be regarded as the elements of that portion of the shaded rock lichen formations which have probably migrated from trees, most widely occurring in such formations over the state. Only one day was spent in studying the New Ulm formations. A second day would have added somewhat to the list, yet doubtless all the dominant lichen floral elements were secured.

Without entering into a detailed analysis, it will appear from an inspection of the lichens composing the formations for shaded and for exposed rocks that the species occurring in the former are for most part foliaceous or fruticulose types, while those given for the latter are in general crustaceous, or if foliaceous, at least closely prostrate on the rocks. This is what would be expected, since shade favors better development of thallus, so that those species showing good thalli crowd out the other species in shaded places, or when unshaded become shaded with the growth of trees.

Next in order come the earth lichen formations of the rocky areas of Granite Falls and New Ulm. I shall first record the exposed formations for the two localities and compare with the similar formation already recorded for Pipestone. Then will follow the lichen formations of shaded earth at the first two stations, which is scarcely developed at Pipestone. A consideration of calcareous-earth lichen formations follows, the present being formations of non-calcareous earth.

Endocarpon hepaticum lichen formation of exposed earth
(Granite Falls).

Heppia despreauxii (MONT.) TUCK.
Urceolaria scruposa (L.) NYL.
Cladonia pyxidata (L.) FR.
Biatora muscorum (SW.) TUCK.
Biatora icterica MONT.
Endocarpon hepaticum ACH.
Endocarpon pusillum HEDW. var. **garovaglii** KPH.

Endocarpon hepaticum lichen formation of exposed earth
(New Ulm).

Cladonia pyxidata (L.) FR., CTS.

Cladonia turgida (Ehrh.) Hoffm.
Biatora uliginosa (Schrad.) Fr.
Endocarpon hepaticum Ach., CT.
Endocarpon pusillum Hedw. var. **garovaglii** Kph., C.

Comparing these lists with the one given for the corresponding formation at Pipestone, we find three common lichens which are marked (C) in the list above. Two of these marked (T) are also found in the similar formation at Taylors Falls, and one marked (S) is common in like formations in the lake Superior region. This plant is the most constant element in the exposed earth lichen formations of the State, and I should be disposed to name these *Cladonia pyxidata* lichen formations, were it not that the plant, though commonly present in exposed stations, thrives better in shaded ones. I must here emphasize that these, as well as the calcareous-earth lichen formations, grow on earth in rocky places where larger vegetation is scanty and scattered.

Next in order come lichen formations of shaded earth, partly composed of plants which grow also, though not so well, in unshaded places. From their dominant elements, these may be designated as follows:

Cladonia-Peltigera lichen formation of shaded earth (Mankato).

Peltigera rufescens (Neck.) Hoffm.
Peltigera canina (L.) Hoffm.
Peltigera canina (L.) Hoffm. var. **sorediata** Schaer.
Collema pulposum (Bernh.) Nyl.
Collema tenax (Sw.) Ach.
Cladonia pyxidata (L.) Fr.
Cladonia fimbriata (L.) Fr.
Cladonia gracilis (L.) Fr.
Cladonia gracilis (L.) Fr. var. **verticillata** Fr.

Cladonia-Peltigera lichen formation of shaded earth (Granite Falls).

Peltigera rufescens (Neck.) Hoffm., CT.
Peltigera canina (L.) Hoffm., CTS.
Peltigera canina (L.) Hoffm. var. **sorediata** Schaer., CTS.
Collema pulposum (Bernh.) Nyl., CT.

Cladonia pyxidata (L.) FR., CTS.
Cladonia fimbriata (L.) FR., C.
Cladonia fimbriata (L.) FR. var. **tubæformis** FR., TS.
Cladonia gracilis (L.) NYL., CTS.
Cladonia gracilis (L.) NYL. var. **verticillata** FR., CTS.

These two formations are remarkably similar, having 8 common forms (C) of a total of nine lichens in each formation. Including the similar formation at Taylors Falls (T) we still have 7 lichens common to the similar formations for a large part of Minnesota, and extending the observation to the similar formation on Grand Portage island in the lake Superior (S) region, we yet have 6 lichens common to such formations selected from widely separated areas in the State. This is the first kind of formation thus far considered which is found in the Minneapolis area studied. Therefore data from this region have not been introduced thus far. Their use in the present consideration would not decrease the number of common elements, and I shall not add them. The three rarer *Cladonias* of the region under consideration in the present paper, *Cladonia symphycarpia* Fr., *Cladonia mitrula* Tuck. and *Cladonia cariosa* (Ach.) Spreng. have been purposely omitted, as there is yet doubt as to whether their adaptation is ombrophytic.

As to the nature of the lichens composing these earth lichen formations, it is apparent that those of the shaded earth formations are as a whole more foliaceous or fruticulose and better developed as to thallus than those of the exposed earth formation. The explanation is of course the same as that already given for exposed and shaded rock lichen formations.

I shall now consider the one remaining earth lichen formation at Granite Falls and compare it with a similar one in another region. It is that of the earth among the calcareous drift pebbles and small boulders on hill sides. From the calcareous nature of the earth and the presence of a *Biatora* seldom seen elsewhere than in such formations, the following name has suggested itself.

Biatora decipiens lichen formation of exposed calcareous earth (Granite Falls).

Heppia despreauxii (MONT.) TUCK.
Heppia polyspora TUCK.

Urceolaria scruposa (L.) NYL.
Biatora muscorum (SW.) TUCK.
Biatora decipiens (EHRH.) FR.
Biatora decipiens (EHRH.) FR. var. **dealbata** AUCT.
Endocarpon hepaticum ACH.

Some of the plants of this formation have been found at Mankato and also at Minneapolis, but the formation is not well developed at either place. However, it is beautifully developed at Fayette, Iowa, and because of its remarkable similarity there to the Granite Falls formation about two hundred miles distant, I give it below for the sake of comparative study.

Biatora decipiens lichen formation of exposed calcareous earth (Fayette, Iowa).

Heppia despreauxii (MONT.) TUCK., C.
Urceolaria scruposa (L.) NYL., C.
Biatora muscorum (SW.) TUCK., C.
Biatora decipiens (EHRH.) FR., C.
Biatora decipiens (EHRH.) FR. var. **dealbata** AUCT., C.
Biatora fossarum (DUF.) MONT.
Endocarpon hepaticum ACH., C.

It will be seen that the two formations are identical except that each one contains one species not found in the other. Again, this slight difference becomes less significant when it is stated that each of these two plants not found in both formations is rather rare in the formation in which it occurs. The six lichens common to both formations I have indicated in the Fayette list (C). In both localities the formations are formed on hill sides and seen to be somewhat better developed on southward than on northward slopes. I have not seen similar formations well developed elsewhere, but it is probable that they reach their best development on unshaded hill sides where other vegetation is scanty and where the lichens are washed with lime-impregnated water flowing down the slope during rains. *Biatora decipiens* (Ehrh.) Fr. and *Endocarpon hepaticum* Ach. are the most common plants of these formations, but the latter is quite as common in another formation of non-calcareous earth, which I have named for it, not confined to hill sides.

Closely related to the above formations are two occupying the same areas and named for a lichen almost wholly confined to them. They follow below:

Lecanora calcarea contorta lichen formation of exposed limestone pebbles (Granite Falls).

Placodium vitellinum (EHRH.) NAEG. and HEPP. var. **aurellum** ACH.

Lecanora calcarea (L.) SOMMERF. var. **contorta** FR.

Lecanora privigna (ACH.) NYL.

Lecanora privigna (ACH.) NYL. var. **pruinosa** AUCT.

Endocarpon pusillum HEDW.

Verrucaria muralis ACH.

Staurothele diffractella (NYL.) TUCK.

Like the last, this formation is not well developed in other studied portions of Minnesota, and I shall give the similar one for Fayette, Iowa, for comparison.

Lecanora calcarea contorta lichen formation of exposed limestone pebbles (Fayette, Iowa).

Placodium cinnabarinum (ACH.) AUZ.

Placodium vitellinum (EHRH.) NAEG. & HEPP. var. **aurellum** ACH., C.

Lecanora muralis (SCHREV.) SCHAER. var. **versicolor** FR.

Lecanora calcarea (L.) SOMMERF.

Lecanora calcarea (L.) SOMMERF. var. **contorta** Fr., C.

Lecanora privigna (ACH.) NYL., C.

Rinodina bischoffii (HEPP.)KOERB.

Biatora russellii TUCK.

Endocarpon pusillum HEDW., C.

Verrucaria nigrescens PERS.

Verrucaria muralis ACH., C.

Lichens common to the two formations are marked (C) in the Fayette list, and comparison shows marked similarity in the two formations about 200 miles distant, except that the latter is considerably better developed than the former. This is as would be expected when we consider that the Iowa region is one where limestones abound, while the Minnesota is one in which the limestone pebbles are those transported in glacial drift and are less numerous. All the species of these formations, except the *Biatoras*, have been found elsewhere in Minnesota, but not aggregated into definite formations.

Comparing the last two series of formations, viz., those of calcareous earth and those of drift pebbles of the same areas, it will be noted that the former, because of their position on dry hill-sides, consist as a whole of lichens having small foliaceous or granular thalli, while those on the yet dryer and harder calcareous pebbles are almost entirely made up of strictly crustaceous plants.

The formations of exposed and shaded limestone bluffs come next in natural order, and the analysis is difficult, since some of the lichens of these formations grow about equally well in sunshine and shade. These I shall indicate by an interrogation point (?). From the prevalence of gelatinous lichens they may be named as follows:

Gelatinous lichen formation of shaded (or damp) limestone bluffs (Mankato).

Pannaria nigra (HUDS.) NYL.
Pannaria languinosa (ACH.) KOERB.
Omphalaria kansana TUCK.?
Omphalaria pulvinata NYL.?
Collema plicatile SCHAER.
Collema pustulatum ACH.
Leptogium lacerum (SW.) FR.
Placodium citrinum (HOFFM.) LEIGHT.
Biatora inundata FR.
Buellia alboatra (HOFFM.) TH. FR. var. **saxicola** FR.
Endocarpon miniatum (L.) SCHAER.
Staurothele umbrina (WAHL.) TUCK.

Similar formations do not exist in other surveyed portions of Minnesota, except at Minneapolis, where the development is poor. It is as follows:

Gelatinous lichen formation of shaded (or damp) calcareous rocks (Minneapolis).

Pannaria nigra (HUDS.) NYL., C.
Pannaria languinosa (ACH.) KOERB., C.

Omphalaria sp.
Leptogium lacerum (Sw.) Fr., C.
Endocarpon miniatum (L.) Schaer., C.
Placodium citrinum (Hoffm.) Leight., C.

The plants of the Minneapolis list are all but one common (C) to both formations and may be regarded as characteristic of such formations. Since the last formation is poorly developed, I may add the similar one for Fayette, Iowa, which is better developed than either of the above.

Gelatinous lichen formation of shaded (or damp) calcareous rocks (Fayette, Iowa).

Pannaria nigra (Huds.) Nyl.
Pannaria languinosa (Ach.) Koerb.
Omphalaria pulvinata Nyl. ?
Omphalaria umbella Tuck. ?
Omphalaria sp.
Collema plicatile Schaer. ?
Collema furvum (Ach.) Nyl. ?
Collema pustulatum Ach. ?
Leptogium lacerum (Sw.) Fr.
Leptogium chlorometum (Sw.) Nyl.
Placodium citrinum (Hoffm.) Leight.
Biatora trachona Flot.
Buellia alboatra (Hoffm.) Th. Fr. var. **saxicola** Fr.
Endocarpon miniatum (L.) Schaer. ?
Staurothele umbrina (Wahl.) Tuck. ?

The introduction of the Fayette formation is of special interest for the following reason. The first Minnesota formation is a mile back from the Minnesota river on a bluff along which the river once flowed, but which now is left dry except for the trees which overhang it and shade the lichens of the formation. The Fayette formation is on a bluff at the water's edge, and the plants are growing within one to ten feet of the water. Doubtless this in part causes the greater richness. The Mankato formation is an interrupted one, none of the plants persisting in wholly unshaded spots. The Fayette formation on the other hand, extends for miles, without complete interruption, wherever the bluffs exist. With the greater amount of moisture at the water's edge, some of the plants of the Fayette formation grow well in sunshine and even on south exposures. These I have indicated by an interrogation point (?). These, for most part gelatinous lichens, require a good amount of moisture; and if growing far from water seek shade for it. In the Fayette locality many trees have been cut recently along the bluffs so that the plants are more exposed than formerly. The Minneapolis list can be considered a formation only in the sense of a group of plants growing under like conditions, for owing to somewhat dryer climate the formation is poorly developed as to individuals and may be designated as a *scattered* formation, only one or two of the species usually growing in one limited area, along the bluffs and long stretches of bluff between these areas frequently not bearing a single plant of the formation.

Next in order comes the lichen formation of exposed limestone bluffs, which I shall designate as follows from the presence of a large proportion of angiocarpous lichens.

Angiocarpous lichen formation of limestone bluffs (Mankato).

Theloschistes lychneus (Nyl.) Tuck.

Placodium elegans (Link.) DC.

Placodium vitellinum (Ehrh.) Naeg. and Hepp var. **aurellum** Ach.

Placodium aurantiacum (Light.) Naeg. and Hepp.

Lecanora hageni Ach.

Lecanora erysibe Nyl.?

Endocarpon pusillum Hedw.?

Endocarpon miniatum (L.) Schaer.?

Staurothele diffractella (Nyl.) Tuck.

Verrucaria fuscella Fr.

Verrucaria nigrescens Pers.

Verrucaria muralis Ach.

I might add similar formations from Minneapolis and Fayette, Iowa; but the analysis is very uncertain so that the comparisons could have little value.

I shall now consider the sandstone bluff formations of certain localities, simply designating them as formations of damp sandstone since they are found along streams where the rocks are well supplied with moisture. The first of the formations is almost completely shaded, but the second is only partially shaded, moisture, the thing really sought by the plants, being sufficient in more or less exposed spots so that the less ombrophytic plants of the group thrive twenty or thirty feet from the water's surface, and even the more shade-loving ones are found in exposed spots nearer the water. I shall now record the formations as follows, designating the less ombrophytic plants of the second formation thus (?). For these formations I suggest the following name from a plant almost wholly confined to them in Minnesota.

Usnea barbata rubiginea lichen formation of damp sandstone bluffs (Minneopa Falls).

Ramalina calicaris (L.) FR. var. **farinacea** SCHAER.
Usnea barbata (L.) FR. var. **hirta** FR.
Usnea barbata (L.) FR. var. **rubiginea** MICHX.
Peltigera canina (L.) HOFFM. var. **sorediata** ACH.
Leptogium chloromelum (SW.) NYL.
Pannaria languinosa (ACH.) KOERB.
Cladonia furcata (HUDS.) FR.
Cladonia furcata (HUDS.) FR. var. **racemosa** FR.
Urceolaria scruposa (L.) NYL.

Usnea barbata rubiginea lichen formation of damp sandstone bluffs (Minneapolis).

Ramalina calicaris (L.) FR. var. **farinacea** SCHAER., C.
Usnea barbata (L.) FR. var. **hirta** FR., C.
Usnea barbata (L.) FR. var. **rubiginea** MICHX. ? C.
Parmelia conspersa (EHRH.) ACH. ? T.
Peltigera canina (L.) HOFFM. var. **sorediata** SCHAER., CE.
Pannaria languinosa (ACH.) KOERB., C.
Lecanora subfusca (L.) ACH. var. **coilocarpa** ACH. ? T.
Urceolaria scruposa (L.) NYL. ? C.
Cladonia cæspiticia (PERS.) FL., T.
Cladonia cornucopioides (L.) FR. ? E.
Endocarpon pusillum (HEDW.) var. **garovaglii** KPH., E.

Comparing the two formations we find six common lichens of a total of nine recorded for the first and eleven for the second. Similar formations occur at Pictured Rocks, Iowa, and at Rapidan, but I shall not multiply lists. As in the instance of certain formations on shaded granite or quartzite recorded above, both of these formations are more or less mixed, being made up of lichens strictly lithophytic in adaptation and of others which have doubtless wandered from trees or from earth. As I have not been able to study such sandstone bluffs at a distance from trees, I have not attempted a definite analysis of these more limited formations as I did for the formations of the shaded granite and quartzite, but have simply indicated in the second list those which have probably wandered from trees by (T) and those from earth by (E). I have omitted from these sandstone formations some of the rarer plants which I should have included had I attempted an analysis of these mixed formations.

I shall now proceed to the two formations of trees, viz., that of rough barked trees and that of trees having smooth bark. The distinctions are difficult in some instances as certain species grow in both habitats. Consequently, as in some instances, in formations previously considered, some plants are recorded for more than one formation. Moreover, it must be added that some of those recorded for rough barked trees frequently seek the smoother portions of the bark. The subfamily *Parmelei* is especially well developed in the rough bark formations, which may accordingly be named as follows:

Parmelei lichen formation of trees with rough bark (Mankato).

Ramalina calicaris (L.) FR. var. **fraxinea** FR., G.
Ramalina calicaris (L.) FR. var. **fastigiata** FR., G.
Theloschistes chrysopthalmus (L.) NORM., G.
Theloschistes polycarpus (EHRH.) TUCK., G.
Theloschistes lychneus (NYL.) TUCK., G.
Theloschistes concolor (DICK.) TUCK., G.
Parmelia perforata (JACK.) ACH.
Parmelia crinita ACH., G.
Parmelia borreri TURN., G.
Parmelia tiliacea (HOFFM.) FLOERK., G.
Parmelia saxatilis (L.) FR.
Parmelia caperata (L.) ACH., G.

Physcia granulifera (ACH.) TUCK., G.
Physcia pulverulenta (SCHREB.) NYL., G.
Physcia stellaris (L.) TUCK., G.
Physcia tribacia (ACH.) TUCK.
Physcia obscura (EHRH.) NYL., G.
Physcia adglutinata (FLOERK.) NYL.
Collema pycnocarpum NYL., G.
Collema flaccidum ACH.
Leptogium myochroum (EHRH., SCHAER.) TUCK.
Placodium aurantiacum (LIGHT.) NAEG. and HEPP., G.
Placodium cerinum (HEDW.) NAEG. and HEPP., G.
Lecanora subfusca (L.) ACH., G.
Pertusaria pustulata (ACH.) NYL.
Pertusaria leioplaca (ACH.) SCHAER.
Pertusaria velata (TURN.) NYL.
Biatora rubella (EHRH.) RABENH.
Biatora fuscorubella (HOFFM.) TUCK., G.
Biatora subfusca FR., G.
Lecidea enteroleuca FR., G.
Buellia alboatra (HOFFM.) TH. FR., G.
Buellia parasema (ACH.) TH. FR.
Opegrapha varia (PERS.) FR., G.
Graphis scripta (L.) ACH., G.
Graphis scripta (L.) ACH. var. limitata ACH., G.
Arthonia lecideella NYL.
Arthonia radiata (PERS.) TH. FR., G.
Coniocybe pallida (PERS.) FR.
Pyrenula gemmata (ACH.) NAEG., G.
Pyrenula hyalospora NYL., G.
Pyrenula nitida ACH.
Pyrenula quinqueseptata (NYL.) TUCK.
Pyrenula leucoplaca (WALLR.) KBR., G.
Pyrenula megalospora sp. nov., G.

In order to avoid reproducing a large portion of the above long list of names, I have for the similar formation at Granite Falls marked those of the list found there (G) and add below the only one found in the Granite Falls formation and not at Mankato, viz., *Biatora naegelii* Tuck. Thus the mark (G) will indicate also those common to both formations and as a whole most characteristic of such lichen formations for the Minnesota valley. The Mankato area with its abundance of trees would, of course, be expected to possess richer tree lichen formations than Granite Falls, and with the exception of a single species, the rough bark formation of the latter area is but a partial repetition of that of the former.

The formation on trees with smooth bark at Mankato contains all but two of the species of the similar formation at Granite Falls, and the treatment may be abbreviated as the last two above. The genus *Pyrenula* predominates in the formation, and some of the species are among the lichens most characteristic of smooth bark. Therefore, the formations may receive the name which follows:

Pyrenula lichen formation of trees with smooth bark (Mankato).

Theloschistes polycarpus (Ehrh.) Tuck.
Theloschistes concolor (Dicks.) Tuck., G.
Parmelia olivacea (L.) Ach., G.
Physcia adglutinata (Floerk.) Nyl., G.
Placodium cerinum (Hedw.) Naeg. and Hepp., G.
Lecanora subfusca (L.) Ach., G.
Rinodina sophodes (Ach.) Nyl., G.
Biatora fuscorubella (Hoffm.) Tuck., G.
Lecidea enteroleuca Fr., G.
Graphis scripta (L.) Ach., G.
Arthonia lecideella Nyl.
Arthonia dispersa Nyl., G.
Pyrenula punctiformis (Ach.) Naeg., F.
Pyrenula punctiformis (Ach.) Naeg. var. **fallax** Nyl., F.
Pyrenula nitida Ach., F.
Pyrenula thelena Ach., F.
Pyrenula cinerella (Flot.) Tuck., F.
Pyrenula cinerella (Flot.) Tuck. var. **quadriloculata** var. nov.
Pyrenula leucoplaca (Wallr.) Kbr., GF.

The two formed on smooth bark at Granite Falls and not at Mankato are *Lecidea enteroleuca* Fr. var. *achrista* Schaer. and *Arthonia punctiformis* Ach. As in the rough bark formations, the one at Mankato is richer for the same reason and, strangely enough, my study of the Granite Falls area only discovered a single *Pyrenula* on smooth bark. My name is scarcely appropriate for this formation, though it is for the one at Mankato as it would be for others from other localities in Minnesota and Iowa which might be added. Without adding another list or another complete formation, I have indicated by (F) in the above list the *Pyrenulas* of that list which occur on smooth bark at Fayette, Iowa.

Persons acquainted with lichen species will readily observe in the lists for rough bark and smooth bark lichen formations, that the formation on rough bark is composed principally of the more foliaceous and fruticulose lichens while those of the smooth bark formations are in the main crustaceous lichens. This is possibly due in part to the fact that these foliaceous and fruticulose lichens more easily gain a foothold on the rough bark which breaks up the thallus of the lichens adapted to smooth bark, thus tending to kill them. However it is probable that light, shade and moisture are also factors, the large trees furnishing more shade than the smaller ones.

Next in order naturally enough we may consider the lichen formations of old boards and old wood, and the formations are so nearly alike for Mankato and Granite Falls that they may be treated in a single list by giving the Mankato list and marking (G) those common to the Granite Falls formation also. Our *Calicei* are lichens seldom seen in any other formations, hence the following name may be applied.

Calicei lichen formation of old boards and wood (Mankato).

Theloschistes chrysopthalmus (L.) NORM., G.

Placodium cerinum (HEDW). NAEG. and HEPP. var. **pyrocea** NYL., G.

Lecanora hageni ACH., G.

Lecanora varia (EHRH.) NYL., G.

Rinodina sophodes (ACH.) NYL., G.

Rinodina sophodes (ACH.) NYL., var. **exigua** FR., G.

Buellia parasema (Ach.) Th. Fr., G.
Buellia turgescens (Nyl.) Tuck.
Calicium parietinum Ach.
Thelocarpon prasinellum Nyl.

The additions for Granite Falls are *Cetraria ciliaris* (Ach.) Tuck., *Lecidea enteroleuca* Fr. and *Calicium quercinum* Ach. As in other instances the common forms are those most characteristic of such formations. I have not detected the *Calicium* for which I have named the Mankato formations at Granite Falls, where it is replaced by another species, and I shall add the species, *Acolium tigillare* (Ach.) Dn., which is one of the *Calicei* common in the similar formation at Fayette, Iowa, and the only one found in the like formation at Minneapolis. It must be admitted that the name used for these formations, while it may be applied, is not so appropriate for the related formations in the lake Superior region where some of the *Calicei* grow on living bark and yet others on rotting wood.

But one formation remains to be considered, viz., that of rotting stumps and prostrate logs. In these formations the most common plants are those of the genus *Cladonia* and the formations may accordingly receive the following name:

Cladonia formation of rotten wood (Mankato).

Peltigera canina (L.) Hoffm., G.
Peltigera canina (L.) Hoffm., var. **servdiata** Schaer.
Cladonia fimbriata (L.) Fr., G.
Cladonia fimbriata (L.) Fr. var. **tubæformis** Fr., G.
Cladonia gracilis (L.) Nyl., G.
Cladonia gracilis (L.) Nyl., var. **verticillata** Fr., G.
Cladonia symphycarpia Tuck.
Cladonia macilenta (Ehrh.) Hoffm.
Cladonia cristatella Tuck.

The only species found at Granite Falls in the similar formation and not at Mankato is *Biatora flexuosa* Fr. and the formation may, with this addition, be indicated by marking (G) those plants of the Mankato formation common to both. Comparison with formations from other localities would show some variation, but the *Cladonias* would predominate and give character to the formations. Wood commonly rots in moist shady places, furnishing an abundance of moisture, and we find accordingly that the formations on rotten wood are made up in large part of fruticulose lichens. The *Calicei* formations of old wood are exposed to drier conditions and are composed almost entirely of lichens having poorly developed thalli.

I must emphasize here that lichens of nearly all the formations enumerated above enjoy moist places, and that lack of moisture produces a decrease in richness both in size and number of individuals and in numbers of species in the formations. I repeat this, which I have established for some parts of Minnesota previously, because some persons may suppose that lichens, because of their xerophytic adaptations, thrive as well in the driest spots as in those affording more moisture. The exceptions to this general statement will appear from a careful study of the analyses made of the various formations.

The gelatinous lichen formation of shaded limestone (Minneapolis) has been called a *scattered* one, and I have explained what is meant by the expression. Others of the same kind are the *Cladonia-Peltigera* lichen formations of shaded earth, the angiocarpous lichen formations of exposed limestone bluffs, the *Calicei* lichen formations of old wood and in some instances the *Cladonia* lichen formations of rotten wood, though in other instances half or more of the species of *Cladonia* of the formation may be found on a single log. Thus formations of the kind last named and like the one first named in this paragraph differs from the other three named in the paragraph in that they may or may not be scattered while the three always are, so far as I know, except the *Calicei* formation which may be found nearly complete on a few rods of old fence in some favorable instances. The two formations of trees are widely extended; but they are not scattered as I have used the term since one commonly finds a good proportion of the species of either formation in passing a short distance in the woods.

Also in my classification we have the peculiar condition of two lichen formations occupying the same area. This is illustrated by the *Biatora decipiens* lichen formation of exposed calcareous earth and the *Lecanora calcarea contorta* lichen formation of exposed limestone pebbles, or by the *Lecanora* lichen formations of exposed granite or quartzite and the *Endocarpon hepaticum* lichen formation of exposed earth. Yet it is apparent that the formations are distinct in both instances, the division being based on substratum as well as amount of light and moisture.

As a whole, the formations may be said to be azonal and without definite form or extent, both depending upon location of proper substrata, protection from or exposure to light, etc.

In my paper I have used the expression "lichen formation" to include lichens only. Of course, these plants are in some instances found growing upon the same substrata and in the same general set of conditions as plants of other groups, and which might have been listed in the formations. However, I may be excused, in a paper on lichen distribution, for omitting other plants than lichens, especially since I could not possibly have treated the other plants with the same detail that I have accorded the lichens.

I know of no other paper which has dealt exclusively with lichen distribution as I have done herein, and surely this analysis must be helpful in the study of the lichen flora of other regions. The multiplicity of observations necessary for such a detailed study are not easy to make, and I am sure that much of interest has escaped me. However, I hope that this paper may stimulate others to study the lichens from an ecologic point of view.

LIST OF SPECIES AND VARIETIES.

1. **Ramalina calicaris** (L.) FR. var. **fraxinea** FR.

On trees and old wood, infrequent or rare. Mankato, June 23, 1899, no. 55, June 26, 1899, no. 102, and June 28, 1899, no. 164. Granite Falls, July 11, 1899, no. 385 and July 13, 1899, nos. 510 and 533.

2. **Ramalina calicaris** (L.) FR. var. **fastigiata** FR.

On trees and rocks, rare. Mankato, June 23, 1899, no. 54. New Ulm, July 5, 1899, no. 275. Granite Falls, July 14, 1899, no. 518, and July 17, 1899, no. 588.

3. **Ramalina calicaris** (L.) FR. var. **farinacea** SCHAER.

On sandstone and granite. Mankato (Minneopa Falls), June 27, 1899, no. 154. Redwood Falls, July 6, 1899, no. 305, and July 8, 1899, no. 349. Granite Falls, July 12, 1899, no. 460.

4. **Ramalina polymorpha** (ACH.) TUCK. ?

On shaded granitic rocks in first locality and on a large bowlder in the second, rare. Granite Falls, July 12, 1899, no.

456, and July 13, 1899, no. 492. Pipestone, July 19, 1899, no. 641.

The plants are placed here provisionally.

They resemble in part *Ramalina calicaris* (L.) Fr. var. *farinacea* Schaer.

Not previously reported from Minnesota and new to the Mississippi valley.

5. **Cetraria ciliaris** (ACH.) TUCK.

A single sterile specimen collected on an old cedar stump. Granite Falls, July 17, 1899, no. 570.

6. **Usnea barbata** (L.) FR. var. **florida** FR.

On an old stump, only seen once and then sterile. Granite Falls, July 17, 1899, no. 565.

7. **Usnea barbata** (L.) FR. var. **hirta** FR.

On sandstone, rare. Mankato (Minneopa), June 27, 1899, no. 151.

8. **Usnea barbata** (L.) FR. var. **rubiginea** MICHX.

On sandstone and granite rocks, rare. Mankato (Minneopa Falls), June 27, 1899, no. 152. Redwood Falls, July 8, 1899, no. 350.

9. **Theloschistes chrysopthalmus** (L.) NORM.

On trees and old boards, rare or infrequent except at Granite Falls, where the plant is frequent. Mankato, June 22, 1899, no. 9. Mankato (Rapidan), June 28, 1899, no. 163. New Ulm, July 4, 1899, nos. 226 and 227. Redwood Falls, July 6, 1899, no. 302, and July 8, 1899, no. 340. Granite Falls, July 11, 1899, no. 387, and July 15, 1899, no. 549.

10. **Theloschistes polycarpus** (EHRH.) TUCK.

On trees and rocks, rare. Mankato, June 26, 1899, no. 107. Granite Falls, July 12, 1899, no. 447, and July 15, 1899, no. 531.

11. **Theloschistes lychneus** (NYL.) TUCK.

On trees and rocks, frequent. Mankato, June 22, 1899, no. 5. New Ulm, July 5, 1899, no. 263. Redwood Falls, July 8, 1899, no. 330. Granite Falls, July 11, 1899, no. 438, and July 17, 1899, no. 579.

12. **Theloschistes concolor** (DICKS.) TUCK.

On trees and old wood, common at the first locality and rare at the second. Mankato, June 22, 1899, no. 7. Granite Falls, July 11, 1899, no. 377.

13. **Theloschistes concolor** (DICKS.) TUCK. var. **effusa** TUCK.

On trees rare. Mankato, July 1, 1899, no. 216a.

14. **Parmelia perforata** (JACQ.) ACH.

On trees, rare. Mankato, June 26, 1899, no. 134.

15. **Parmelia cetrata** ACH.

On trees and rocks, rare except at the last locality where the plant is frequent. New Ulm, July 4, 1899, no. 228. Redwood Falls, July 8, 1899, nos. 329 and 360. Granite Falls, July 12, 1899, no. 455, and July 17, 1899, nos. 550, 573 and 574.

16. **Parmelia crinita** ACH.

On trees and granitic rocks, rare. Mankato, June 23, 1899, no. 47. Mankato (Minneopa Falls), June 27, 1899, no. 133. New Ulm, July 5, 1899, no. 258. Granite Falls, July 11, 1899, nos. 400 and 439.

17. **Parmelia borreri** TURN.

On trees and granitic rocks, common. Mankato, June 22, 1899, no. 11. New Ulm, July 5, 1899, no. 288. Redwood Falls, July 8, 1899, no. 335. Granite Falls, July 11, 1899, nos. 383 and 389.

18. **Parmelia borreri** TURN. var. **rudecta** TUCK.

On trees and old wood, infrequent. Mankato, June 23, 1899, no. 12, and July 23, 1899, no. 58.

19. **Parmelia borreri** TURN. var. **hypomela** TUCK.

On shaded granite rocks, rare and sterile. New Ulm, July 5, 1899, no. 287.

20. **Parmelia tiliacea** (HOFFM.) FLOERK.

On trees, infrequent. Mankato, June 23, 1899.

21. **Parmelia saxatilis** (L.) FR.

On trees and rocks, rare. Mankato, June 26, 1899, no. 106. New Ulm, July 5, 1899, no. 264. Redwood Falls, July 8, 1899, no. 341. Granite Falls, July 11, 1899, no. 414.

22. **Parmelia saxatilis** (L.) FR. var. **sulcata** NYL.

On old wood and shaded rocks, rare. Mankato (Rapidan), June 28, 1899, no. 165. Granite Falls, July 17, 1899, no. 586.

23. **Parmelia saxatilis** (L.) FR. var. **panniformis** (ACH. (SCHAER.?

On shaded rocks, rare. New Ulm, July 5, 1899, no. 268. Granite Falls, July 17, 1899, no 561.

The plant is placed here provisionally.

Not previously reported from Minnesota and new to the Mississippi valley.

24. **Parmelia olivacea** (L.) Ach.

On trees and old wood, rare. Mankato, June 23, 1899, no. 61. Granite Falls, July 15, 1899, no. 537.

25. **Parmelia olivacea** (L.) ACH. var. **prolixa** ACH.

On granitic rocks, quartzite, pipestone and once collected on earth, frequent except at the first locality, where it is rare. Morton, July 7, 1899, no. 315. Granite Falls, July 11, 1899, no. 405. Pipestone, July 18, 1899, nos. 594, 609 and 621, and July 19, 1899, no. 643.

26. **Parmelia caperata** (L.) ACH.

On trees and granitic rocks, frequent. Mankato, June 23, 1899, no. 53. Mankato (Minneopa) June 27, 1899, no. 153. New Ulm, July 5, 1899, no. 285. Granite Falls, July 11, 1899, no. 441.

27. **Parmelia conspersa** (EHRH.) ACH.

On granitic rocks, quartzite and pipestone, common or abundant. New Ulm, July 5, 1899, no. 269. Granite Falls, July 12, 1899, no. 449. Pipestone, July 18, 1899, no. 589, and July 19, 1899, no. 637.

28. **Physcia speciosa** (WULF., ACH.) NYL.

On rocks and mossy bases of trees, infrequent. Mankato, June 22, 1899, no. 13. New Ulm., July 5, 1899, no. 281. Granite Falls, July 11, 1899, no. 374.

29. **Physcia granulifera** (ACH.) TUCK.

On trees, rare. Mankato, June 24, 1899, no. 84. Granite Falls, July 11, 1899, no. 372.

30. **Physcia pulverulenta** (SCHREB.) NYL.

On rocks and trees, frequent. Mankato, June 23, 1899, no. 52. New Ulm, July 5, 1899, no. 286. Granite Falls, July 11, 1899. no. 383.

31. **Physcia stellaris** (L.) TUCK.

On trees and rocks, common or abundant. Mankato, June 23, 1899, no. 1. New Ulm, July 5, 1899, no 297. Granite Falls, July 11, 1899 no. 431, and July 13, 1899, no. 481.

32. **Physcia stellaris** (L.) TUCK. var. **apiola** NYL.

On granitic rocks, infrequent. Mankato, June 23, 1899, no. 44. Granite Falls, July 12, 1899, no. 463.

33. **Physcia tribacia** (ACH.) TUCK.

On wood, granite and quartzite, rare. Mankato, June 23, 1899, no. 77, and July 1, 1899, no. 216. Granite Falls, July 14, 1899, no. 517. Pipestone, July 18, 1899, no. 601 and July 19, 1899, no. 634.

34. **Physcia cæsia** (HOFFM.) NYL.

On bowlders and all kinds of rocks in the region, except limestone, frequent. Mankato, June 23, 1899, no. 76. New Ulm, July 5, 1899, nos. 290 and 296. Granite Falls, July 12, 1899, no. 443. Pipestone, July 18, 1899, nos. 618 and 624.

35. **Physcia obscura** (EHRH.) NYL.

On trees and rocks, common. Mankato, June 1899, no. 76a. New Ulm, July 5, 1899, no. 289. Granite Falls, July 11, 1899, no. 378, and July 17, 1899, no. 583.

36. **Physcia adglutinata** (FLOERK.) NYL.

On trees, frequent. · Mankato, June 23, 1899, no. 45. Granite Falls, July 11, 1899, no. 382 and July 13, 1899, no. 482.

37. **Pyxine sorediata** FR.

On granitic rocks, rare. Granite Falls, July 17, 1899, no. 578.

38. **Peltigera rufescens** (NECK.) HOFFM.

On earth and mossy rocks, frequent. Mankato, June 25, 1899, no. 48. Mankato (Minneopa Falls), June 27, 1899, no. 150. New Ulm, July 5, 1899, no. 251. Granite Falls, July 11, 1899, no. 395 and July 17, 1899, no. 559.

39. **Peltigera canina** (L.) HOFFM.

On earth and rocks, common. Mankato (Minneopa Falls), June 27, 1899, no. 149. New Ulm, July 5, 1899, no. 262. Granite Falls, July 11, 1899, no. 390, and July 17, 1899, no. 580.

40. **Peltigera canina** (L.) HOFFM. var. **spongiosa** TUCK.

On earth, rare. Redwood Falls, July 8, 1899, no. 357.

Not previously reported from Minnesota.

41. **Peltigera canina** (L.) HOFFM. var. **spuria** ACH.

On earth, rare. Mankato (Rapidan), June 28, 1899, no. 161.

42. **Peltigera canina** (L.) HOFFM. var. **sorediata** SCHAER.

On earth and old wood, rare, Mankato, June 26, 1899, no. 121. New Ulm, July 5, 1899, no. 260. Granite Falls, July 13, 1899, no. 512.

43. **Peltigera horizontalis** (L.) Hoffm.

On shaded earth, frequent locally. Redwood Falls, July 6, 1899, no. 301.

44. **Heppia despreauxii** (Mont.) Tuck.

On earth, rare at first locality and frequent at second. Mankato (Rapidan) June 28, 1899. no. 177. Granite Falls, July 11, 1899, no. 394, July 13, 1899, no. 507 and July 14, 1899, no. 522.

Not previously reported from Minnesota.

45. **Heppia polyspora** Tuck.?

On earth, rare. Granite Falls, July 13, 1899, no. 498. Spores spherical or subspherical, $\frac{5-8}{5-8}$ mic. This exceeds Tuckerman's measurements. Apothecia occasionally surpassing one mm. in diameter. I may later find it necessary to separate this as new species.

Not previously reported from Minnesota.

46. **Pannaria languinosa** (Ach.) Koerb.

On various rocks, earth and trees in shaded places, common or abundant. Mankato, June 23, 1899, no. 50. New Ulm, July 5, 1899, no. 280. Granite Falls, July 11, 1899, no. 396, and July 17, 1899, no. 569.

47. **Pannaria microphylla** (Sw.) Delis.

On shaded granite, infrequent. Redwood Falls, July 8, 1899, no. 345. Granite Falls, July 11, 1899, no. 384.

48. **Pannaria nigra** (Huds.) Nyl.

On limestone, common locally. Mankato, June 24, 1899, no. 95.

49. **Ephebe pubescens** Fr.

On quartzite, rare. New Ulm, July 5, 1899, no. 257.

50. **Pyrenopsis phæococca** Tuck.

On bowlders, rare. Mankato, June 23, 1899, no. 74.

Not previously reported from Minnesota and new to the Mississippi valley.

51. **Pyrenopsis melambola** Tuck.?

On bowlders, frequent. Mankato, June 29, 1899, no. 189. Spores somewhat small (7–10 x 4–5½ mic.).

Not previously reported from Minnesota and new to the Mississippi valley.

52. **Omphalaria kansana** TUCK.

On limestone, locally frequent. Mankato, June 23, 1899, no. 27.

Not previously reported from Minnesota.

53. **Omphalaria pulvinata** NYL.

On limestone, rare. Mankato, June 27, 1899, no. 148.

Not previously reported from Minnesota.

54. **Omphalaria phyllisca** (WAHL.) TUCK.

On granitic rocks, rare. Redwood Falls, July 6, 1899, no. 360, and July 8, 1899, nos. 338 and 343. Granite Falls, July 17, 1899, nos. 572 and 584.

Not previously reported from Minnesota and new to the Mississippi valley.

55. **Collema pycnocarpum** NYL.

On trees and once on rocks, generally distributed in the Minnesota valley, but rare.

Mankato, June 23, 1899, no. 60, and June 24, 1899, nos. 89 and 97. Mankato (Minneopa Falls), June 27, 1899, no. 136. Redwood Falls, July 6, 1899, no. 309, and July 8, 1899, no. 355. Granite Falls, July 11, 1899, no. 380.

56. **Collema flaccidum** ACH.

On trees and rocks, rare. Mankato, June 23, 1899, no. 81. Mankato (Minneopa), June 27, 1899, no. 137. New Ulm, July 5, 1899, no. 278.

57. **Collema pulposum** (BERNH.) NYL.

On earth and rocks, common in first locality. Mankato, June 22, 1897, no. 3, and June 23, 1899, no. 79. Granite Falls, July 11, 1899, no. 417.

58. **Collema tenax** (SW.) ACH.

On earth, rare. Mankato (Rapidan), June 28, 1899, no. 169.

Not previously reported from Minnesota.

59. **Collema plicatile** SCHAER.

On calcareous rocks, locally frequent. Mankato, June 23, 1899, no. 28.

Not previously reported from Minnesota.

60. **Collema pustulatum** ACH.

On calcareous rocks, rare. Mankato, June 26, 1899, no. 111.

Not previously reported from Minnesota.

61. **Collema furvum** (ACH.) NYL.

On shaded rocks, infrequent. New Ulm, July 5, 1899, no. 283. Redwood Falls, July 6, 1899, no. 307. Granite Falls, July 11, 1899, no. 391.

Not previously reported from Minnesota.

62. **Leptogium lacerum** (SW.) FR.

On various rocks, usually shaded, frequent. Mankato, June 23, 1899, no. 49. Redwood Falls, July 8, 1899, no. 328. Granite Falls, July 13, 1899, nos. 480 and 497 and July 17, 1899, no. 568.

63. **Leptogium pulchellum** (ACH.) NYL.

Collected once on a large bowlder in a shaded ravine, rare. Mankato, July 1, 1899, no. 212.

Not previously reported from Minnesota.

64. **Leptogium chloromelum** (SW.) NYL.

On mossy, shaded sandstone, rare. Mankato (Minneopa Falls), June 27, 1899, no. 144.

65. **Leptogium myochroum** (EHRH., SCHAER.) TUCK.

On trees and shaded granitic rocks, rare. Mankato, June 26, 1899, no. 126. Mankato (Rapidan), June 28, 1899, no. 166. Granite Falls, July 11, 1899, no. 392.

66. **Placodium elegans** (LINK.) DC.

On various rocks; common at Granite Falls, infrequent elsewhere. Mankato, June 24, 1899, no. 83. Redwood Falls, July 8, 1899, no. 353. Granite Falls, July 11, 1899, no. 440. Pipestone, July 18, 1899, nos. 592 and 603.

67. **Placodium murorum** (HOFFM.) DC.

On granitic rocks, rare. Granite Falls, July 12, 1899, no. 452.

68. **Placodium cinnabarrinum** (ACH.) AUZ.

On various rocks, frequent or common. Mankato, June 23, 1899, no. 73, and June 30, 1899, no. 200. Morton, July 7, 1899, no. 320. North Redwood, July 10, 1899, no. 369. Granite Falls July 11, 1899, no. 411. Pipestone, July 18, 1899, no. 607.

69. **Placodium aurantiacum** (LIGHTF.) NAEG. and HEPP.

On trees and rocks, common at first locality. Mankato, June 22, 1899, no. 19, and June 23, 1899. no. 38. Granite Falls, July 11, 1899, no. 375.

70. **Placodium citrinum** (HOFFM.) LEIGHT.

On limestone, rare. Mankato, June 26, 1899, no. 117.

71. **Placodium cerinum** (HEDW.) NAEG. and HEPP.

On trees and old wood, common. Mankato, June 22, 1899, no. 18, and June 23, 1899, no. 75. Mankato (Rapidan), June 28, 1899, nos. 178 and 179. Granite Falls, July 11, 1899, nos. 432 and 435. Granite Falls, July 17, 1899, no. 553.

72. **Placodium cerinum** (HEDW.) NAEG. and HEPP. var. **sideritis** TUCK.

On granitic rocks and catlinite, common. Mankato, June 23, 1899, no. 41, June 26, 1899, no. 114, and June 30, 1899, no. 198. New Ulm, July 5, 1899, no. 247. Granite Falls, July 12, 1899, no. 444. Pipestone, July 18, 1899, no. 613.

73. **Placodium cerinum** (HEDW.) NAEG. and HEPP. var. **pyracea** NYL.

On old boards, infrequent. Mankato, June 22, 1899, no. 2. Granite Falls, July 11, 1899, no. 430.

74. **Placodium ferrugineum** (HUDS.) HEPP.

On old wood, rare. Mankato, June 22, 1899, no. 17. Not previously reported from Minnesota.

75. **Placodium ferrugineum** (HUDS.) HEPP. var. **pollinii** TUCK.

On dead cedars, rare. New Ulm, July 4, 1899, no. 230. Not previously reported from Minnesota.

76. **Placodium vitellinum** (EHRH.) NAEG. and HEPP.

On granite and quartzite, common. Mankato, June 30, 1899, no. 203. New Ulm, July 5, 1899, no. 292. Granite Falls, July 12, 1899, no. 462. Pipestone, July 18, 1899, no. 629.

77. **Placodium vitellinum** (EHRH.) NAEG. and HEPP. var. **aurellum** ACH.

On granite, quartzite and sandstone, frequent. Mankato, June 22, 1899, no. 10. New Ulm, July 4, 1899, nos. 233, 237 and 239. Granite Falls, July 14, 1899, no. 523.

78. **Lecanora** sp.

On granitic rocks, frequent locally. Granite Falls, July 11, 1899, no. 408. Spores $\frac{13\text{–}16}{8\text{–}9.5}$ mic. Seems near *Lecanora gelida* (L.) Ach., but the thallus is probably too rough and heavy.

Not previously reported from Minnesota and new to the Mississippi Valley.

79. **Lecanora rubina** (VILL.) ACH.

On granite, quartzite and pipestone, common. Mankato (Rapidan), June 28, 1899, no. 160. New Ulm, July 5, 1899, no. 248. Granite Falls, July 11, 1899, no. 401 and July 12, 1899, no. 451. Pipestone, July 18, 1899, no. 617, and July 19, 1899, no. 644.

80. **Lecanora rubina** (VILL.) ACH. var. **heteromorpha** ACH.

With the last, frequent. New Ulm, July 5, 1899, no. 266. North Redwood, July 10, 1899, no. 361. Granite Falls, July 11, 1899, no. 409. Pipestone, July 18, 1899, and July 19, 1899, no. 642.

81. **Lecanora muralis** (SCHREB.) SCHAER.

On calcareous rocks, granite and quartzite, common at Granite Falls, rare elsewhere. Mankato, June 24, 1899, no. 85. Granite Falls, July 11, 1899, no. 406. Pipestone, July 18, 1899, no. 630.

82. **Lecanora muralis** (SCHREB.) SCHAER. var. **versicolor** FR.

On calcareous rocks, rare. Mankato, June 30, 1899, no. 196.

83. **Lecanora muralis** (SCHREB.) SCHAER. var. **saxicola** SCHAER.

On granitic rocks and catlinite, frequent. Mankato, June 30, 1899, no. 202. North Redwood, July 10, 1899, no. 370. Pipestone, July 19, 1899, no. 638.

84. **Lecanora frustulosa** (DICKS.) MASS.

On rocks, rare. Redwood Falls, July 8, 1899, no. 351. North Redwood, July 10, 1899, no. 371. Granite Falls, July 11, 1899, no. 410.

85. **Lecanora subfusca** (L.) ACH.

On trees and rocks, common at Mankato only. Mankato, June 23, 1899, no. 43, and June 26, 1899, no. 125. New Ulm, July 5, 1899, no. 271. Granite Falls, July 11, 1899, no. 376.

86. **Lecanora subfusca** (L.) ACH. var. **allophana** ACH.

On granitic rocks, infrequent. Granite Falls, July 11, 1899, nos. 403 and 407.

Not previously reported from Minnesota:

87. **Lecanora subfusca** (L.) ACH. var. **argentata** ACH.

On trees, rare. Mankato, June 23, 1899, no. 78.

88. **Lecanora subfusca** (L.) Ach. var. **coilocarpa** Ach.

On trees, granite and sandstone, rare. Mankato (Rapidan), June 28, 1899, no. 163a. Mankato, July 1, 1899, no. 210. Granite Falls, July 12, 1899, no. 446.

89. **Lecanora subfusca** (L.) Ach. var. **distans** Ach.

On sandstone, rare. Mankato (Rapidan), June 28, 1899, no. 182.

90. **Lecanora hageni** Ach.

On calcareous and granitic rocks and on old boards, common. Mankato, June 21, 1899, no 91, and July, 1, 1899, nos. 215, 217 and 218. Granite Falls, July 11, 1899, nos. 426 and 436, and July 13, 1899, no. 506.

91. **Lecanora varia** (Ehrh.) Nyl.

On old wood and trees, infrequent. Mankato, June 24, 1899, no. 86. Mankato (Rapidan), June 28, 1899, no. 159. New Ulm, July 5, 1899, no. 280. Granite Falls, July 11, 1899, no. 386.

92. **Lecanora erysibe** Nyl.

On granitic rocks, rare. Mankato, June 23, 1899, no. 63, and June 26, 1899, no. 131. Granite Falls, July 13, 1899, no. 504.

93. **Lecanora cinerea** (L.) Sommerf.

On granite, quartzite and catlinite, common. Mankato, June 6, 1899, no. 62. New Ulm, July 5, 1899, no. 261. Granite Falls, July 13, 1899, no. 493. Pipestone, July 18, 1899, nos. 625 and 633.

94. **Lecanora cinerea** (L.) Sommerf. var. **lævata** Fr.

On quartzite, rare. New Ulm, July 5, 1899, no. 277.

95. **Lecanora cinerea** (L.) Sommerf. var. **gibbosa** Nyl.

On bowlders, rare. Mankato, July 1, 1899, no. 221.

96. **Lecanora calcarea** (L.) Sommerf.

On limestone, rare. Mankato, June 29, 1899, no. 188.

97. **Lecanora calcarea** (L.) Sommerf. var. **contorta** Fr.

On limestone, drift pebbles and granite, infrequent. Mankato, June 30, 1899, no. 199. Redwood Falls, July 8, 1899, no. 333. Granite Falls, July 11, 1899, no. 402, and July 14, 1899, no. 524.

98. **Lecanora xanthophana** Nyl.

On granite, quartzite and pipestone, common. Mankato, June 30, 1899, no. 197. New Ulm, July 5, 1899, no. 246. Morton, July 7, 1899, no. 313. Redwood Falls, July 8, 1899, no. 331. North Redwood, July 10, 1899, no. 368. Granite Falls, July 11, 1899, no. 418. Pipestone, July 18, 1899, nos. 598 and 611.

99. **Lecanora cervina** (Pers.) Nyl.

On bowlders and sandstone, infrequent. Mankato (Rapidan), June 28, 1899, no. 179. Mankato, June 29, 1899, no. 192.

100. **Lecanora cervina** (Pers.) Nyl. var. **cinereoalba** var. nov.

On granite, frequent. Mankato, June 29, 1899, no. 190. Granite Falls, July 11, 1899, nos. 385 and 403, and July 12, 1899, no. 404.

Thallus gray or grayish white.

101. **Lecanora fuscata** (Schrad.) Th. Fr.

On bowlders, common at Mankato. Mankato, June 29, 1899, no. 191. Granite Falls, July 12, 1899, no. 450.

102. **Lecanora bookii** (Fr.) Th. Fr.

On limestone, rare. Mankato, June 29, 1899, no. 193.

Not previously reported from Minnesota and new to the Mississippi valley.

103. **Lecanora privigna** (Ach.) Nyl.

On sandstone and calcareous drift pebbles, rare. Mankato (Rapidan), June 28, 1899, no. 171. Granite Falls, July 13, 1899, no. 508.

104. **Lecanora privigna** (Ach.) Nyl. var. **pruinosa** Auct.

With last on same substrata, rare. Mankato (Rapidan), June 28, 1899, no. 170. Granite Falls, July 14, 1899, no. 514.

105. **Rinodina oreina** (Ach.) Mass.

On granitic rocks, quartzite and catlinite, abundant. Mankato, June 30, 1899, no. 201. New Ulm, July 5, 1899, no. 245. North Redwood, July 10, 1899, no. 367. Pipestone, July 18, 1899, nos. 602, 603 and 605.

106. **Rinodina sophodes** (Ach.) Nyl.

On trees, old wood and rocks, abundant. Mankato, June 23, 1899, no. 33, June 24, 1899, no. 93, and June 26, 1899, no. 115. New Ulm, July 5, 1899, nos. 267, 295 and 298. Granite Falls, July 11, 1899, nos. 427 and 428, and July 13, 1899, nos. 469, 486, 487 and 491.

107. **Rinodina sophodes** (Ach.) Nyl. var. **tephraspis** Tuck.

On quartzite, rare. Pipestone, July 18, 1899, no. 632.

Not previously reported from Minnesota.

108. **Rinodina sophodes** (Ach.) Nyl. var. **exigua** Fr.

On old wood, locally common. Mankato, June 22, 1899, no. 22. Granite Falls, July 11, 1899, no. 434.

109. **Rinodina bischoffii** (Hepp.) Koerb.

On limestone and granite, rare. Mankato, June 29, 1899, no. 194. Morton, July 7, 1899, no. 316.

Not previously reported from Minnesota.

110. **Rinodina lecanorina** Mass.

On boulders, rare. Mankato, June 26, 1899, no. 127.

Not previously reported from Minnesota and new to North America.

111. **Pertusaria velata** (Turn.) Nyl.

On trees, rare. Mankato (Minneopa Falls), June 26, 1899, no. 135.

112. **Pertusaria pustulata** (Ach.) Nyl.

On trees, rare. Mankato, June 23, 1899, no. 30, and July 1, 1899, no. 214.

113. **Pertusaria leioplaca** (Ach.) Schaer.

On trees, rare. Mankato, June 23, 1899, no. 68.

114. **Urceolaria scruposa** (L.) Nyl.

On earth and rocks, infrequent. Mankato, June 26, 1899, no. 128. Mankato (Rapidan), June 28, 1899, no. 187. Redwood Falls, July 8, 1899, no. 332. Granite Falls, July 11, 1899, no. 393. Pipestone, July 19, 1899, no. 640.

115. **Urceolaria actinostoma** Pers.

On granite, rare. Granite Falls, July 11, 1899, no. 416.

Not previously reported from Minnesota.

116. **Stereocaulon paschale** (L.) Fr.

On mossy rocks, only seen once in small quantity. Redwood Falls, July 8, 1899, no. 359.

117. **Cladonia symphycarpia** Fr. var. **epiphylla** (Ach.) Nyl.

On earth, rare. Mankato, June 26, 1899, no. 108.

118. **Cladonia mitrula** Tuck.

On earth, rare. Mankato, June 26, 1899, no. 98. Granite Falls, July 11, 1899, no. 436. The last a small form approaching *Cladonia cæspiticia* (Pers.) Fl.

119. **Cladonia cariosa** (ACH.) SPRENG.

On earth, rare. Mankato, June 26, 1899, no. 103. Redwood Falls, July 8, 1899, no. 336. Granite Falls, July 17, 1899, no. 587.

120. **Cladonia pyxidata** (L.) FR.

On earth, common or frequent. Mankato, June 26, 1899, no. 104. Mankato (Rapidan), June 28, 1899, no. 168. New Ulm, July 5, 1899, nos. 272 and 276, July 11, 1899, no. 397, July 12, 1899, no, 453, and July 17, 1899, no. 562. Pipestone, July 18, 1899, no. 627.

121. **Cladonia fimbriata** (L.) FR.

On earth, rare. Mankato, June 26, 1899, no 123. Granite Falls, July 12, 1899, no. 582. Pipestone, July 18, 1899, no. 604.

122. **Cladonia fimbriata** (L.) FR. var. **tubæformis** FR.

On old wood and earth, rare. Mankato, June 26, 1899, no. 124. New Ulm, July 5, 1899, no. 279. Granite Falls, July 11, 1899, no. 425, July 13, 1899, no. 495, and July 17, 1899, nos. 551 and 563.

123. **Cladonia fimbriata** (L.) FR. var. **radiata** FR.

On earth, rare. Redwood Falls, July 8, 1899, no. 337.

124. **Cladonia gracilis** (L.) NYL.

On old wood and earth, frequent at Mankato, elsewhere rare. Mankato, June 22, 1899, no. 4, and June 26, 1899, no. 100. Granite Falls, July 13, 1899, nos. 468 and 488, and July 17, 1899, no. 556.

125. **Cladonia gracilis** (L.) NYL. var. **symphycarpia** TUCK.

On old wood, rare. Mankato, June 26, 1899, no. 99.

126. **Cladonia gracilis** (L.) NYL. var. **verticillata** FR.

On earth, rare. Mankato, June 26, 1899, no. 101. Granite Falls, July 17, 1899, no. 557.

127. **Cladonia gracilis** (L.) NYL. var. **hybrida** SCHAER.

On earth, rare. Mankato (Rapidan), June 28, 1899, no. 158. Redwood Falls, July 8, 1899, no. 347.

128. **Cladonia turgida** (EHRH.) HOFFM.

On earth, rare. New Ulm, July 5, 1899, no. 253.

129. **Cladonia cæspiticia** (PERS.) FL.

On earth, rare. Redwood Falls, July 8, 1899, no. 342. Granite Falls, July 17, 1899, no. 555.

130. **Cladonia furcata** (Huds.) Fr.

On earth, rare. Mankato (Minneopa Falls), June 27, 1899, nos. 155 and 157.

131. **Cladonia furcata** (Huds.) Fr. var. **racemosa** Fl.

On earth in shaded places, rare. Mankato (Minneopa Falls), June 27, 1899, no. 156. Redwood Falls, July 8, 1899, no. 334.

132. **Cladonia furcata** (Huds.) Fr. var. **pungens** Fr.

On earth, rare. Redwood Falls, July 6, 1899, no. 303.

133. **Cladonia rangiferina** (L.) Hoffm.

On earth, frequent locally among granitic rocks. New Ulm, July 5, 1899, no. 252.

134. **Cladonia rangiferina** (L.) Hoffm. var. **sylvatica** L.

On earth, rare. Redwood Falls, July 8, 1899, no. 358.

135. **Cladonia macilenta** (Ehrh.) Hoffm.

On old wood, rare. Mankato, June 29, 1899, no. 195.

136. **Cladonia cristatella** Tuck.

On old stumps, rare. Mankato (Rapidan), June 28, 1899, no. 162. Redwood Falls, July 8, 1899, no. 356. Granite Falls, July 13, 1899, no. 467 and July 17, 1899, no. 575.

137. **Cladonia cristatella** Tuck. var. **paludicola** Tuck.

Once collected on an old log. Mankato, June 26, 1899, no. 122. Squamules not powdery.

Not previously reported from Minnesota, and new to the upper Mississippi valley.

138. **Biatora decipiens** (Ehrh.) Fr.

Common on earth containing calcareous drift pebbles. Granite Falls, July 13, 1899, no. 500.

Not previously reported from Minnesota.

139. **Biatora decipiens** (Ehrh.) Fr. var. **dealbata** Auct.

Common on earth with the last. Granite Falls, July 13, 1899, no. 499.

Not previously reported from Minnesota.

140. **Biatora icterica** Mont.

On earth, rare. Granite Falls, July 11, 1899, no. 398, and July 18, 1899, no. 519.

141. **Biatora rufonigra** Tuck.

On granitic rocks and quartzite, common. New Ulm, July 5, 1899, no. 265. Morton, July 7, 1899, no. 325. Granite Falls, July 12, 1899, no. 454.

142. **Biatora coarctata** (SM., NYL.) TUCK.

On limestone and sandstone, rare. Mankato, June 26, 1899, no. 113. Mankato (Rapidan), June 28, 1899, no. 173.

142*a*. **Biatora coarctata** (SM., NYL.) TUCK. var. **brugeriana**, SCHAER.

On sandstone, locally abundant. Mankato (Minneopa Falls), June 27, 1899, nos. 139, 142, 145 and 146. Mankato (Rapidan), June 29, 1899, nos. 172, 174 and 176.

143. **Biatora uliginosa** (SCHRAD.) FR.

On earth, infrequent. Mankato, June 26, 1899, no. 128. New Ulm, July 5, 1899, no. 250.

144. **Biatora myriocarpoides** (NYL.) TUCK.

On quartzite, locally common. New Ulm, July 5, 1899, no. 300.

145. **Biatora varians** (ACH.) TUCK.

On trees, probably frequent locally. Granite Falls, July 15, 1899, no. 502.

146. **Biatora flexuosa** FR.

On dead cedar, rare. Granite Falls, July 13, 1899, no. 477. Not previously reported from Minnesota.

147. **Biatora hypnophila** (TURN.) TUCK.

On earth and limestone, rare. Mankato, June 23, 1899, no. 36, and June 26, 1899, no. 120.

148. **Biatora nægelii** HEPP.

On trees, infrequent. Granite Falls, July 13, 1899, no. 484, and July 15, 1899, no. 530.

149. **Biatora rubella** (EHRH.) RABENH.

On trees, common locally. Mankato, June 23, 1899, no. 35, and June 26, 1899, no. 130. Mankato (Minneopa Falls), June 27, 1899, no. 138.

150. **Biatora fuscorubella** (HOFFM.) TUCK.

On trees and rocks, common at Mankato, elsewhere rare or infrequent. Mankato, June 23, 1899, no. 29. Mankato (Minneopa Falls), June 27, 1899, no. 141. New Ulm, July 5, 1899, no. 274. Granite Falls, July 15, 1899, nos. 529 and 536.

151. **Biatora suffusa** FR.

On trees, rare. Mankato, June 23, 1899, no. 37. Granite Falls, July 15, 1899, no. 540.

Not previously reported from Minnesota.

152. **Biatora muscorum** (Sw.) Tuck.

On earth, frequent and once on sandstone. Mankato, July 1, 1899, no. 220. New Ulm, July 4, 1899, no. 237. Redwood Falls, July 8, 1899, no. 344. Granite Falls, July 11, 1899, no. 433. Pipestone, July 18, 1899, nos. 590 and 591.

153. **Biatora inundata** Fr.

On limestone and sandstone, common. Mankato, June 22, 1899, no. 24. New Ulm, July 4, 1899, no. 234.

154. **Lecidea enteroleuca** Fr.

On trees, common at Granite Falls. Mankato, June 23, 1899, no. 80, and July 1, 1899, no. 209. New Ulm, July 4, 1899, no. 231. Redwood Falls, July 8, 1899, no. 354. Granite Falls, July 11, 1899, no. 429, July 13, 1899, nos. 476, 479, 485 and 496, and July 14, 1899, no. 516.

155. **Lecidea enteroleuca** Fr. var. **achrista** Sommerf.

On trees, frequent. Granite Falls, July 13, 1899, nos. 471 and 475, and July 15, 1899, no. 546.

156. **Buellia spuria** (Schaer.) Arn.

On granitic rocks, quartzite and pipestone, frequent or common. New Ulm, July 5, 1899, no. 294. Morton, July 7, 1899, no. 324. Granite Falls, July 12, 1899, nos. 445 and 458. Pipestone, July 18, 1899, no. 612.

157. **Buellia alboatra** (Hoffm.) Th. Fr.

On trees, especially *Ulmus*, rare at first locality and more common at second. Mankato, June 22, 1899, no. 15. Granite Falls, July 11, 1899, no. 382, and July 17, 1899, no. 577.

158. **Buellia alboatra** (Hoffm.) Th. Fr. var. **saxicola** Fr.

On limestone, shaded, rare. Mankato, June 22, 1899, no. 16. Not previously reported from Minnesota.

159. **Buellia parasema** (Ach.) Th. Fr.

On trees, infrequent. Mankato, June 23, 1899, no. 34, and June 24, 1899, no. 85. New Ulm, July 3, 1899, no. 224. Granite Falls, July 11, 1899, no. 388.

160. **Buellia myriocarpa** (DC.) Mudd.

On old wood, common or frequent. Mankato, June 22, 1899, no. 20. Mankato (Rapidan), June 28, 1899, no. 184. Granite Falls, July 17, 1899, no. 552.

161. **Buellia pullata** TUCK.

On rocks, frequent. Morton, July 7, 1899, no. 327. North Redwood, July 10, 1899, nos. 365 and 366. Granite Falls, July 11, 1899, no. 405. Pipestone, July 18, 1899, no. 600.

Not previously reported from Minnesota.

162. **Buellia turgescens** (NYL.) TUCK.

On old boards, rare. Mankato, June 22, 1899, no. 21.

Not previously reported from Minnesota.

163. **Buellia petræa** (FLOT., KOERB.) TUCK.

On granite, quartzite and pipestone, abundant. New Ulm, July 5, 1899, nos. 242 and 293. Redwood Falls, July 6, 1899, no. 306. Granite Falls, July 11, 1899, no. 422.

164. **Buellia petræa** (FLOT., KOERB.) TUCK. var. **montagnæi** TUCK.

On same rocks as last and even more abundant; however, only a single collection on a bowlder at first locality. Mankato (Rapidan), June 28, 1899, no. 183. Morton, July 7, 1899, nos. 318 and 321. North Redwood, July 10, 1899, no. 362. Granite Falls, July 11, 1899, no. 422a. Pipestone, July 18, 1899, nos. 593 and 620.

165. **Opegrapha varia** (PERS.) FR.

On trees, abundant. Mankato, June 23, 1899, no. 40, June 26, 1899, no. 110, and July 1, 1899, no. 204. Granite Falls, July 11, 1899, nos. 419 and 421, July 13, 1899, no. 483, and July 15, 1899, nos. 539 and 548.

166. **Opegrapha varia** (PERS.) FR. var. **pulicaris** (HOFFM.) FR.

On trees, rare. Granite Falls, July 15, 1899, no. 528.

Not previously reported from Minnesota.

167. **Graphis scripta** (L.) ACH.

On trees, common at Mankato. Mankato, June 22, 1899, no. 14. Granite Falls, July 13, 1899, no. 503.

168. **Graphis scripta** (L.) ACH. var. **recta** (HUMB.) NYL.

On birches, rare. Mankato (Minneopa Falls), June 27, 1899, no. 141a.

169. **Graphis scripta** (L.) ACH. var. **limitata** ACH.

On trees, rare. Mankato, June 22, 1899, no. 23. Granite Falls, July 13, 1899, no 469, and July 15, 1899, no. 538.

170. **Arthonia lecideella** NYL.

On trees, infrequent. Mankato, June 23, 1899, no. 69.

171. **Arthonia dispersa** (SCHRAD.) NYL.

On trees, common. Mankato, June 22, 1899, no. 25, and July 23, 1899, no. 72. Granite Falls, July 13, 1899, no. 490.

172. **Arthonia radiata** (PERS.) TH. FR.

On trees, infrequent. Mankato, June 23, 1899, no. 70. Granite Falls, July 13, 1899, no. 489, and July 15, 1899, no. 532.

173. **Arthonia punctiformis** ACH.

On maples, rare. Granite Falls, July 15, 1899, no. 341a.

173*a*. **Arthonia** sp.

On trees, rare. Granite Falls, July 15, 1899, no. 541.

With general appearance of *Arthonia dispersa* (Schrad.) Nyl., but the colorless spores are four celled and $\frac{22-26}{7.5-8.5}$ mic.

Not previously reported from Minnesota.

174. **Calicium parietinum** ACH.

On old wood, probably rare. Mankato, June 22, 1899, no. 8, and June 24, 1899, no. 87, Redwood Falls, July 8, 1899, no. 326.

175. **Calicium quercinum** PERS.

Collected once only, on cedar. Granite Falls, July 13, 1899, no. 478.

176. **Coniocybe pallida** (PERS.) FR.

On a large oak, only once collected. Mankato, July 7, 1899, no. 206.

177. **Endocarpon miniatum** (L.) SCHAER.

Abundant on limestone bluffs, frequent on granite and rare on quartzite. Mankato, June 23, 1899 no. 46 and June 25, 1899, no. 59. Redwood Falls, July 6, 1899, no. 312. Granite Falls, July 11, 1899, no. 373, and July 13, 1899, no. 474. Pipestone, July 18, 1899, no. 606.

178. **Endocarpon miniatum** (L.) SCHAER. var. **complicatum** SCHAER.

On substrata noted above and also on pipestone, frequent. Mankato, June 25, 1899, no. 57. New Ulm, July 5, 1899, no. 249. North Redwood, July 10, 1899, no. 363. Granite Falls, July 12, 1899, no. 448, and July 13, 1899, no. 495. Pipestone, July 18, 1899, no. 615, and July 19, 1899, no. 639.

179. **Endocarpon fluviatile** DC.

On rocks frequently wet, infrequent. Morton, July 7, 1899, no. 322. Granite Falls, July 12, 1899, 448a.

180. **Endocarpon arboreum** SCHWEIN.

On trees and shaded rocks, once seen on each. Redwood Falls, July 6, 1899, no. 308, and July 8, 1899, no. 339.

Not previously reported from Minnesota.

181. **Endocarpon hepaticum** ACH.

On earth and sandstone, common. Mankato (Rapidan), June 28, 1899, no. 175. New Ulm, July 4, 1899, no. 235, and July 5, 1899, no. 244. North Redwood, July 10, 1899, no. 364. Granite Falls, July 11, 1899, no. 384. Pipestone, July 18, 1899, no. 623.

182. **Endocarpon pusillum** HEDW.

On limestone bluffs, sandstone, calcareous drift pebbles, and once on earth, common. Mankato, June 23, 1899, no. 39. New Ulm, July 4, 1899, no. 236. Granite Falls, July 12, 1899, no. 442, July 13, 1899, no. 509, and July 14, 1899, no. 526.

183. **Endocarpon pusillum** HEDW. var. **garovaglii** KPH.

On earth and sandstone, frequent. Mankato, July 1, 1899, no. 219. Mankato (Rapidan), June 28, 1899, no. 186. New Ulm, July 5, 1899, no. 282. Morton, July 7, 1899, no. 317. Pipestone, July 18, 1899, no. 616.

184. **Thelocarpon prasinellum** NYL.

On old wood and sandstone, frequent. Mankato, June 22, 1899, no. 6, and June 26, 1899, no. 132.

I cannot bring that on sandstone under any of the rock species, and it seems to belong here.

185. **Staurothele umbrina** (WAHL.) TUCK.

On granite, limestone and quartzite, frequent. Mankato, June 23, 1899, no. 82. Granite Falls, July 11, 1899, no. 412, July 15, 1899, no. 547, and July 17, 1899, no. 566.

186. **Staurothele diffractella** (NYL.) TUCK.

On sandstone, granite, quartzite and calcareous drift pebbles, rare. New Ulm, July 4, 1899, nos. 238 and 240. Granite Falls, July 13, 1899, no. 501, and July 17, 1899, no. 560.

Not previously reported from Minnesota.

187. **Staurothele drummondii** Tuck.

On granite, quartzite and pipestone, common in damp places at Granite Falls and Pipestone. Redwood Falls, July 8, 1899, no. 327. Granite Falls, July 12, 1899, no. 457, July, 13, 1899, no. 494, and July 17, 1899, no. 554. Pipestone, July 18, 1899, nos. 595, 619, 622 and 628.

188. **Verrucaria fuscella** Fr.

On limestone, infrequent. Mankato, June 23, 1899, no. 42.

188*a*. **Verrucaria nigrescens** Pers.

On limestone common and once seen on a granite bowlder. Mankato, June 23, 1899, no. 65, June 24, 1899, no. 96, and June 26, 1899, no. 116.

189. **Verrucaria muralis** Ach.

On limestone in bluffs and drift pebbles, abundant at Mankato. Mankato, June 22, 1899, no. 26. Granite Falls, July 13, 1899, no. 511, and July 14, 1899, no. 525.

190. **Pyrenula punctiformis** (Ach.) Naeg.

On trees, infrequent. Mankato, June 24, 1899, nos. 90 and 94.

191. **Pyrenula punctiformis** (Ach.) Naeg. var. **fallax** Nyl.

On birch, infrequent. Mankato, June 24, 1889, no. 66, and June 26, 1899, no. 109.

192. **Pyrenula gemmata** (Ach.) Naeg.

On trees frequent. Granite Falls, July 14, 1899, no. 513.

Not previously reported from Minnesota.

193. **Pyrenula hyalospora** Nyl.

On trees, probably rare. Mankato, June 23, 1899, no. 32, and June 25, 1899. Granite Falls, July 13, 1899, no. 470.

Not previously reported from Minnesota.

194. **Pyrenula nitida** Ach.

On trees, rare. Mankato, July 1, 1899, no. 211. New Ulm, July 3, 1899, no. 222.

195. **Pyrenula thelena** (Ach.) Tuck.

On birch, common. Mankato (Minneopa Falls), June 27, 1899, no. 140.

196. **Pyrenula cinerella** (Flot.) Tuck.

On trees, infrequent. Mankato (Minneopa Falls), June 27, 1899, no. 143.

Spores reaching 12–16 by 6–8 mic. in one collection. Thus larger than usual American forms.

197. **Pyrenula cinerella** (Flot.) Tuck. var. **quadriloculata** var. nov.

On birch, probably rare. Mankato, June 26, 1899, no. 129. Mankato (Rapidan), June 28, 1899, no. 163a.

Second time collected in Minnesota and both times from hosts of same genus.

198. **Pyrenula quinqueseptata** (Nyl.) Tuck.

On trees, rare. Mankato, July 1, 1899, no. 208.

Spores frequently showing 8 cells, which is not common for the species.

Not previously reported from Minnesota.

199. **Pyrenula leucoplaca** (Wallr.) Kbr.

On trees, common. Mankato, June 23, 1899, no. 31. Mankato (Rapidan), June 28, 1899, no. 180. Mankato, July 1, 1899, no. 207. Granite Falls, July 13, 1899, no. 464, and July 15, 1899, nos. 527, 535 and 543.

200. **Pyrenula glabrata** (Ach.) Mass.

On trees, rare. Mankato, June 24, 1899, no. 88.

Not previously reported from Minnesota.

201. **Pyrenula megalospora** sp. nov.

Thallus rather smooth, indeterminate, prominent, gray or grayish white. Apothecia scattered or occasionally aggregated in clusters of two or three, black or brownish black, convex with the ostiole-bearing apex somewhat pointed, semi-immersed or becoming more superficial, .4 to .75 mm. in diameter. Amphithecium white. Paraphyses capillary and very distinct. Asci cylindrical, .25 to .3 mm. in length. Spores colorless, 2-celled, oblong with ends obtuse or somewhat pointed, somewhat constricted at the septum, large for 2-celled spores of the genus (35–60 by 14–21 mic.), 8 in asci, crowded and obliquely uniseriate.

On trees, frequent. Mankato, June 26, 1899, no. 112 and July 1, 1899, no. 209. Granite Falls, July 11, 1899, no. 381 and July 11, 1899, no. 576.

XX. A SYNONYMIC CONSPECTUS OF THE NATIVE AND GARDEN AQUILEGIAS OF NORTH AMERICA.

K. C. Davis.

The name *Aquilegia* (Linn. Sp. Pl. 533, 1753) is probably not from *aquila*, eagle, as commonly given, but from *aquilegus*, water-drawer. The name may have been applied from the supposed power of the roots to extract water from rocks, among which they so often grow. They are commonly called Columbines.

Hardy perennial herbs, mostly with paniculate branches terminated by showy flowers ; leaves 1–3 times ternately compound, commonly glaucous ; leaflets roundish and obtusely lobed : flowers large, showy, appearing usually in spring or early summer ; sepals 5, regular, petaloid ; petals concave, produced backward between the sepals forming a hollow spur ; stamens numerous ; fruit of about 5 many-seeded follicles.

About 30 species are distinct ; all of the north temperate regions of the world. Nearly half of these (12) are natives of North America. Most of the native species and varieties are used in American and European gardens, and ten foreign species have already been introduced here. *Aquilegia* furnishes many useful, ornamental forms eminently fitted for choice mixed borders and beds. A good, deep, rather sandy, well drained soil is the best. Seeds sown in pans, in cold frames in March, or open air in April, occasionally bloom the first season, but generally the second. The seed germinates slowly, and the ground should be kept moist on top during this period. The different species should, if possible, be kept some distance apart if pure seed is desired, as the most divers species hybridize directly. They may be propagated by root division but better by seed. Absolutely pure seed is hard to obtain except from the plants in the wild state ; and some of the mixed forms are quite inferior to the true species from which they have come. *A. cærulea*, *A. glandulosa*, and *A. vulgaris* are apt to flower only two or three years from the same plant and should be treated as biennials; but *A. vulgaris* may be kept active for a longer period by transplanting.

The latest extended accounts of species in this group are by J. G. Baker, in *Gardener's Chronicle*, 1878; and B. L. Robinson, in *Gray's Synoptical Flora*, 1: 42–45, 1895.

In presenting this and the accompanying paper, I desire to extend thanks to all who have so kindly aided me in my studies of Ranunculaceous genera; particularly I am under obligations to Professor L. H. Bailey for many valuable suggestions at times of greatest need and for placing about me the largest collection of colored plant portraits and the largest garden herbarium in America, and to Professor W. W. Rowlee for placing at my disposal not only the entire collection of herbarium specimens in the department of botany of Cornell University, but also numerous living roots and plants from which to better study vegetative characters.

KEY TO SPECIES OF AQUILEGIA.

A. Sepals not more than ½ or ¾ inch long; expanded flower 1 or 1½ inches in diameter.
    B. Limb of petal shorter than the sepal.
        C. Stem-leaves present; stem 1½-to 2½ feet high.
            D. Spur straight, not knobbed.................... *lactiflora.*
            DD. Spur knobbed, bent inward................ *oxysepala.*
        CC. Stem-leaves wanting; stem reduced to a short scape. *Jonesii.*
    BB. Limb of petal about equal to the sepal.
        C. Leafless or nearly so; stem scapiform.......... *elegantula.*
        CC. Leaves two or more on a stem.
            D. Plant low, slender (commonly 6–8 inches); spurs incurved.
                E. Leaves, stems and follicles pubescent. *brevistyla.*
                EE. Leaves, stems and follicles smooth. *saximontana.*
            DD. Plant one foot high or more; spurs nearly straight.
                E. Stamens protruding beyond the petal-limbs.
                    F. Spurs somewhat knobbed...... *Canadensis.*
                    FF. Spurs not knobbed............. *viridiflora.*

EE. Stamens hardly protruding or shorter than petal-limb.
  F. Plant finely pubescent above. *Buergeriana.*
  FF. Plant glandular-pubescent and viscid above. ....*micrantha.*

AA. Sepals about one inch long; expanded flower about two inches in diameter.
  B. Spurs shorter than the petal limb, and incurved....*flabellata.*
  BB. Spurs at least as long as the petal-limb.
    C. Stamens short, not much protruding.
      D. Spurs only slightly curved, not knobbed...*leptoceras.*
      DD. Spurs much incurved or coiled.
        E. Follicles densely pubescent..............*vulgaris.*
        EE. Follicles glabrous.......................*Sibirica.*
    CC. Stamens long, protruding far beyond the petal-limb.
      D. Sepals green, keeled; young fruits winged. *Skinneri.*
      DD. Sepals usually yellow or red, not keeled; fruits never winged...*formosa.*
  BBB. Spurs very long, often several times as long as petal-limbs.
    C. Length of spur about 1 or 1¼ inches...........*pubescens.*
    CC. Length of spur about 2 inches................*chrysantha.*
    CCC. Length of spur 4 inches or more...........*longissima.*

AAA. Sepals 1¼ to 1½ or even 2 inches long; expanded flower 2½ to 3 inches in diameter; stamens not protruding.
  B. Spurs long and not incurved.................................*cærulea.*
  BB. Spurs incurved and not longer than the petal-limbs.
    C. Follicles few, pubescent...............................*alpina.*
    CC. Follicles 6–10; densely hairy...................*glandulosa.*

A. lactiflora KAR. & KIR. in Mosc. Bull. **15**: 374. 1841. Stem 1½ feet high, glabrous in the lower part: partial-petioles of root leaves 1½ to 2 inches long, leaflets sessile or short stalked, 1 inch long, many lobes reaching half way down; stem leaves petioled and compound; flowers about 3 on a stem; sepals nearly white, or tinged with blue, over ½ inch long, narrow; petal-limb half as long as the sepal; spur ⅓ inch, slender, nearly straight, not knobbed at tip; stamens equal in length to the limb. June. Altai Mts., Siberia. A desirable species but not much used in gardens.

A. oxysepala TRAUT. & MEYER. in Middend. Reise. Florula Ocho. Phæn. 10. 1856.

Plant 2½ feet high, slightly pubescent above: radical leaves long-petioled, secondary divisions sessile: sepals ovate-lanceolate, much exceeding the petal-limbs in length, which are 6 lines long, white, rounded-truncate; stamens not protruding beyond the petal-limb; spur knobbed, bent inward, shorter than petal-limb: follicles pubescent with styles their own length. June. Eastern Siberia. In 1898 F. H. Horsford said of this: "the first to bloom with me, and one of the most attractive in the list. It is one of the most dwarfed; flowers large, blue, yellow and white: it comes so much before the others that its capsules, as a rule, all fertilize before any of the other species come into flower."

A. Jonesii PERRY, Am. Nat. 8: 211. 1874.

True stem very short or almost wanting, soft-pubescent: tufted root-leaves an inch or two high from the stout, ascending branches of the rootstock; biternately divided partial petioles very short or none; leaflets very crowded: flowers blue; sepals oblong, obtuse, equalling the spurs and twice the length of the petal limbs and head of stamens: follicles glabrous, large, nearly 1 inch long, styles ½ as long; peduncles lengthening to about 3 inches in fruit. July. N. W. Wyoming, Mont., to Brit. Am. Garden & Forest, 9: 365.

A. elegantula GREENE, Pitt. 4: 14. 1899.

Erect, slender, mostly less than a foot high, glabrous except on the inflorescence, the peduncle and exterior of the flowers hirtellous-pubescent; stem scapiform, usually only bracted; radical leaves long-petioled, glabrous beneath: flowers mostly solitary, terminal, small, about 1 inch long, sepals light green, erect; petal-limbs light yellow, erect; spurs straight, longer than the sepals, rather widely inflated above and light scarlet in that part; filaments short; styles exserted. June. Slide Rock Cañon, and in Spruce woods Mt. Hesperus, S. Colo. Described from the original. Type in Greene's Herbarium (†).

A. brevistyla HOOK. Fl. Bor Am. 1: 24. 1833.

A. vulgaris RICHARDS. in Frankl. Jl. App. 740. 1823, not Linn.

A. vulgaris var. *brevistyla* GRAY, Am. Journ. Sci. Ser. 2, 33: 242. 1862.

A. Laramiensis A. NELSON Wyom. Exp. Sta. Bull. 28: 78. 1895–6.

Slender, 6–15 inches high, glandular-pubescent above at least, several flowered: root–leaves biternate, long-petioled, leaflets lobed and crenate; stem-leaves few, lower ones short-petioled: flowers blue with yellowish petals, small, about as broad as long; petals and sepals about equal in length, stamens a little shorter, spurs even shorter and incurved: follicles pubescent, equalling the flower in length, ⅔ inch, becoming erect. May–June. Mts. of Northwest Territory into South Dakota (†).

A. saximontana P. A. RYDBERG ex Robinson, Syn. Fl. 1: 1: 43. 1895.

Stem from a scaly rootstock, less than six inches high: leaves, stems and follicles smooth throughout, otherwise like above. Mts. Colo. (†).

A. Canadensis LINN. Sp. Pl. 533. 1753.
A. variegata MOENCH. Meth. 311. 1794.
A. elegans SALISB. Prod. 374. 1796.

Height 1–2 feet; primary divisions of petioles of root-leaves 1–2 inches, having 3 divisions; 2 or 3 of the stem leaves petioled, biternate: flowers several on a stem; sepals yellowish or tinted on the back with red, about ½ inch long, not reflexing; limb of petals a little shorter, yellowish, truncate; spur ¾ inch long, nearly straight, knobbed at the end, bright red throughout; stamens much protruding: follicles ¾ inch long, with style ½ as long. May–July. Stony banks, etc. East of the Rocky Mts. Introduced 1890. Bot. Mag. 246. Loddiges' Bot. Cab. 888. Meehan's Mo. 5: 21.

Var. **flaviflora** BRITTON Bull. Torr. Club, **15**: 97. 1888.
A. flaviflora TENNEY Am. Nat. **1**: 388. 1867.
A. cærulea var. *flavescens* LAWSON Rev. Canad. Ranun. 75. 1870.
A. flavescens WATS. Bot. King. Exp. 10. 1871.

Flowers a clear yellow. Very pretty. Introduced 1889. Bot. Mag. 6552 B. (as *A. formosa* var. *flavescens*).

Var. **depauperata** n. var.
A. depauperata JONES Contr. West. Bot. No. 8, 1. 1898.

Stems slender; leaves and leaflets smaller than the type; flowers also small, cream colored tinged with blue and green. June. Along streams, and in Provo Cañon, Utah. Collected by M. E. Jones, who has the type (†).

Var. **nana** HORT. Plant 1 foot high or less; flowers like the type.

A. viridiflora PALLAS in Act. Petrop. 260, t. 2. 1779.

Stem 1–1½ feet high, finely pubescent throughout, several flowered: the partial petioles of root-leaves 1–2 inches long; leaflets sessile or the end one shortly stalked, lobes rather narrow and deep; lower stem-leaves petioled, biternate: sepals oblong, obtuse, ascending, greenish, equalling the broad, greenish petal-limb, but not reaching the head of stamens; spur straight, slender, ½ inch long, not knobbed; pubescent follicles as short as their styles. Summer. East Siberia. Not so much used as the following variety.

Var. **atropurpurea** n. var.

A. atropurpurea WILLD. Enum. Hort. Berol. 577. 1813.

A. dahurica PATR. in Deless. Ic. Sel. t. 49. 1820.

Limbs of the petals deep blue or lilac-purple, and the sepals and spur somewhat tinged with the same hue. Bot. Reg. 922.

A. Buergeriana SIEB. & ZUCC. in Abh. Akad. München. **4**: II, 183. 1846.

A. atropurpurea MIQUEL. Ann. Mus. Lugd. Bot. **3**: 8. 1867.

One foot high, finely pubescent towards the top; branched to form several heads, bearing 2–3 petioled, biternate leaves; partial-petioles of basal leaves ½–1 inch long, 3 sessile divisions; flowers yellow tinted with purple, 1–1½ inch in diameter; sepals ¾ inch long, acute, spreading; spurs erect, nearly straight, as long as the limb of petal, and about equalling the sepal; head of stamens equal to limb in length: follicles pubescent, ¾ inch long, style half as long. Early. Japan. Brought from St. Petersburg, 1892.

A. micrantha EASTWOOD, Proc. Cal. Acad. Sci. II, **4**: 559. *t. 19*. 1894.

Stem slender, densely glandular-pubescent and viscid on upper parts: leaflets small, cuneate, 3-cleft, with 2–3-lobed segments; partial-petioles of the lateral leaflets short: flowers hardly 1 inch across, yellowish white; sepals nearly ½ inch long, nearly half as broad: petals rather truncate, spur short, straight, or slightly curved. July. Cañons of southeast Utah to Colorado (†).

Var. **ecalcarata** n. var.

A. ecalcarata EASTWOOD in Zoe, **2**: 226. 1891; **4**: 3. 1893.

Flowers sometimes reddish, fragrant: spurs sometimes reduced to mere sacs, but with intermediated grades to the type form (†).

A. flabellata SIEB. & ZUCC. in Abh. Akad. Münch. **4**: II, 183. 1846.

A. vulgaris Thunb. Fl. Jap. 232. 1784. Not Linn.

A. glandulosa Miq. in Ann. Mus. Lugd. Bat. **3**: 8. 1867.

Stem 1 to 1½ feet high, few flowered: partial-petioles of root-leaves 1 inch or more, leaflets nearly sessile; stem-leaves large and petioled: flowers bright lilac, or pale purple, or white; sepals 1 inch long, obtuse; limb of petal ½ as long, often white in the lilac flowered form; spur shorter than the limb, slender toward the end, much incurved; stamens not protruding beyond the petal-limbs: follicles glabrous. Summer. Japan. Revue Hort. 109. 1896. Revue Belg. 15: 157.

Var. **nana-alba** HORT., *A. flabellata* var. *flore-albo* HORT. Flowers pure white and the plant dwarfish.

A. leptoceras FISCH. & MEYER. Ind. Hort. Petrop. **4**: 33. 1837.

A. brachyceras TURCZ. ex F. & M. Maund. Bot. Gard. no. 755. About 1842.

Stem several flowered, about 1 ft. high: partial-petioles of root-leaves over 1 inch, leaflets sessile; stem-leaves petioled, biternate: flowers violet, with the tips of the sepals greenish, and tips of the short petal-limbs yellow; spur slender, slightly curved, ½ inch long, not knobbed; stamens protruding a little beyond the limbs of the petals: follicles slender, glabrous, nearly 1 inch long. Summer. East Siberia. Bot. Reg. 33: 64. Flor. des Serr. 3: 296. Little used in America.

A. vulgaris LINN. Sp. Pl. 533. 1753.

A. inversa MILL. Gard. Dict. 8 ed. no. 3. 1768.

A. silvestris NECK. Delic. Gallo-Belg. **1**: 234. 1768.

A. cornuta GILIB. Fl. Lituan, **2**: 286. 1781.

A. versicolor SALISB. Prod. 374. 1796.

A. corniculata VILL. Cat. Hort. Strasb. 250. 1807.

A. stellata HORT. ex Steud. Nom. 1 ed. 61. 1821.

A. elata LEDEB. Ind. Hort. Dorp. Suppl. 41. 1824.

A. atrata KOCH. in Flora, **13**: 1. 118. 1830.

A. nigricans BAUMG. Enum. Stirp. Trans. **2**: 104. About 1830.

A. Haenkeana KOCH. Syn. Fl. Germ. 23. 1837.

A. concoler FISCH. ex Steud. Nom. 2 ed. **1**: 115. 1840.

A. ecalcarata HORT. ex Steud. l. c. 115.

A. elegans POPE ex Steud. l. c. 115.

A. sibirica DON ex Steud. l. c. 115.

A. subalpina BOR. Fl. Centr. Fr. 3 ed. **2**: 24. 1840.

A. Bernardi GREN. & GODR. Fl. Fr. **1**: 45. 1848.

A. Transsilvanica SCHUR. Vehr. Siebenb. Ver. Nat. **3**: 94. 1852.

A. sylvestris SCHUR. Vehr. Siebenb. Ver. Nat. **4**: 4. 1853.

A. glaucophylla STEUD. in Flora, **39**: 407. 1856.

A. aggericola JORD. Diagn. **1**: 87. 1860.

A. collina JORD. l. c. 84.

A. dumeticola JORD. l. c. 86.

A. praecox JORD. l. c. 85.

A. paraplesia SCHUR. Enum. Pl. Trans. 28. 1866.

A. corsica SOLIER. ex Nym. Consp. 18. 1878.

A glaucescens BAKER, l. c. 203.

A. Karelini BAKER l. c. 76.

A. subscaposa BORHAS in Magyar Tudom. Akad. **12**, IV, 18. 1882.

A. platysepala REICHB. Ic. Fl. Germ. *t. 4730*. About 1886.

Stem 1½–2 feet high, many flowered; finely pubescent throughout: root-leaves with 3 partial-petioles 1½–2 inches long, secondary branches certain, ultimate leaf lobes shallow and roundish, texture firm; lower stem-leaves petioled and biternate: flowers violet to dark purple; sepals ovate, furnished with a claw, acute, 1 inch long, one-half as wide; petal-limb ¾ inch long, equalling the head of stamens; spur about same length, stout, much incurved, knobbed: follicles densely pubescent, 1 inch long, style half as long. Summer. Europe, Siberia, and naturalized in America. Garden 12, p. 288.

Var. **nivea** BAUMG. ex Baker Gard. Chron. II, **10**: 76. 1878. Var. *alba* HORT. Often 2–3 feet high: a great profusion of large, pure white flowers. Several weeks in early spring.

Var. **flore-pleno** HORT. *A. plena* Hort. Flowers much doubled, ranging from pure white to deep blue.

Var. **cervæneana** HORT. Var. *folio-aureis* HORT. Var. *atroviolacea* HORT. Leaves with yellow variegated lines.

Var. **Olympica** BAKER l. c.
A. Olympica BOIES. in Ann. Sc. Nat. II, 16: 360.
A. blanda LEW. Ill. Hort. 4: *t. 146*. 1857.
A. Caucasica LEDEB. ex Rupr. Fl. Caus. 32. 1869.
A. Wittmanniana STEV. ex F. & M. l. c.

A fine variety with several large flowers; sepals light lilac or bright purple, 1 inch or more in length, petal-limb white. Revue Hort. 1896, p. 108.

Var. **hybrida** SIMS. Bot. Mag. 1221. 1809.

Much like the last variety, but with stout, lilac-purple spurs as long as the sepals, only slightly incurved. Probably a hybrid of *A. vulgaris* and *A. canadensis*.

A. Sibirica LAM. Encyc. 1: 150. 1783.
A. bicolor EHRH. Beitr. 7: 246. 1792.
A. speciosa DC. Syst. 1: 336. 1818.
A. Garnieriana SWEET Brit. Fl. Gard. II, 5: *t. 103*. 1833.

Stem 1½–2 feet high, many flowered; stem nearly glabrous throughout: flowers pale or bright lilac-blue; oblong sepals fully 1 inch long, spreading or reflexed a little; petal-limb half as long, equalling the head of stamens, and often white; spur rather stout, ½ inch or more, very much incurved or even coiled: follicles glabrous, 1 inch long, style ⅓ inch. Allied to *A. vulgaris*, differing in the broad, obtuse sepals; spur long and more slender toward the tip, and glabrous follicles. Summer. East Siberia. Sweet's Brit. Fl. Gard. II, *t. 90 & t. 103*.

Var. **spectabilis** BAKER l. c. *A. spectabilis* LEM. Ill. Hort. 403, 1864. A large, bright lilac-flowered variety with petal-limbs tipped with yellow. Amurland.

Var. flore-pleno HORT. *A. bicolor* var. *flore-pleno* HORT. Flowers much doubled by the multiplication of both the limbs and the spurs.

H. Skinneri HOOK. in Bot. Mag. 3919. 1842.
A. Mexicana HOOK., l. c.

Stem 1–2 feet high, many flowered, glabrous: root-leaves long-petioled, with both primary and secondary divisions long, leaflets cordate, 3-parted; several stem-leaves petioled and biternate: sepals, green, keeled, lanceolate, acute, never much spreading, ¾–1 inch long: petal-limb greenish-orange, half as long as sepal; spur bright red, tapering rapidly, over 1 inch long; stamens protruding far beyond the limb: fruit, at least when young, bearing broad, membranous, curled wings; styles 3; after flowering the peduncles become erect. July-Sept. Mts. of New Mex. and Mex. Bot. Mag. 3919. Paxt. Mag. Bot. 10: 199. Flor. des Serr. 1: 17. A handsome plant, requiring a light soil in a sunny border.

Var. flore-pleno HORT. Flowers double. Very fine. Gartenflora 34: 57.

A. formosa FISCH. in DC. Prod. 1: 50. 1824.
A. artica LOUD. Hort. Brit. 610. 1830.
A. Canadensis var. *formosa* WATS. Bot. King Exp. 10. 1871.

Habit as *A. Canadensis*, root-leaves and stem-leaves like that species, but the flowers are brick red and yellow or wholly yellow, and the sepals are larger, twice as long as the petal-limb, more spreading: spurs somewhat more slender and often shorter. May–Aug. Sitka to Calif. and eastward to the Rockies. Introduced 1881. Bot. Mag. 6552. Flor des Serr. 8: 795.

Var. desertorum JONES Cont. Western. Bot. No. 8, 2. 1898. Stems about one foot high, flexuose: leaves and leaflets rather small: flowers often only about ¾ inch across, nodding: styles slender. In crevices of rocks about springs. Flagstaff, Ariz. (†).

Var. **truncata** BAKER l. c.; JONES Zoe, 4: 259. 1893.
A. truncata FISCH. & MEY. 1843.
A. Californica LINDL. in Gard. Chron. 836. 1854.
A. eximia VANHOUTTE ex Planch. Fl. des Serr. **12**: 1188. 1857.

Flowers with short thick spurs and very small sepals and petal-limbs. Introduced 1881.

Var. **hybrida** HORT. *A. Californica* var. *hybrida* HORT. Flowers large with scarlet sepals and yellow petals; spurs spreading, long and slender. A supposed hybrid with *A. chrysantha*. Fl. Mag. 1877: 278. Vicks' 1: 33, *f. 2.*

Var. **nana-alba** HORT. Flowers pale, often nearly white; plant not exceeding 1 foot.

Var. **rubra-pleno** HORT. Flowers as in var. *hybrida*, but with several whorls of petal-limbs.

A. pubescens COVILLE Contr. Nat. Herb. **4**: 56, *pl. 1.* 1893. Allied to *A. chrysantha.* Caudex scaly; flowers a very clear yellow; spurs shorter, only 1 to 1½ inches; petal-limbs a third as long as sepals. July. High altitudes Tulare Co., Calif.

A. chrysantha GRAY in Gard. Chron. 1335 and 1501, *f. 304.* 1873.

A. leptoceras var. *chrysantha* HOOK. f. Bot. Mag. 6073. 1873.

A. leptoceras var. *flava* GRAY Pl. Wright 2: 9. 1852.

Height 3–4 feet: root-leaves with twice 3-branched petioles, leaflets biternate: stem-leaves several, petioled: flowers many on the plant; 2–3 inches across; sepals pale yellow, tinted claret, spreading horizontally; petal-limbs deep yellow, shorter than the sepals and nearly as long as the head of stamens; spur rather straight, very slender, divergent, about 2 inches long, descending when flower is mature; follicles glabrous, 1 inch long; style half as long. May–Aug. New Mex. and Ariz. Introduced 1891. Revue Hort. 1896: 108. Flor. des Serr. 20; 2108. Floral Mag. 1873: 88. Dict. d. Bot. 1: 243. Vicks' 1: 33, *f. 3.*

Var. **aurea** n. var.

A. aurea JUNKA. in Oestr. Bot. Zeitschr. 22: 174. 1872.

A. Canadensis var. *aurea* ROEZL., Gartenflora 258, *t. 734.* 1872.

Flowers yellow and tinged with red, spurs incurved and shorter than in the type. Gartenflora 21: 734.

Var. **alba-plena** HORT. Var. *grandiflora-alba* HORT. Flowers very pale yellow or nearly white, with two or more whorls of petal-limbs. Introduced. 1889. Vicks' 12: 311.

Var. **nana** HORT. *A. leptoceras* var *lutea* HORT. Like the type, but plant always small, not exceeding 1½ feet.

Var. **Jaeschkani** HORT. About the same height as the last: flowers large, yellow with red spurs. Thought to be a hybrid of *A. chrysantha* and *A. Skinneri*, hence sometimes called *A. Skinneri* var. *hybrida* HORT.

A. longissima GRAY ex Wats. Proc. Am. Acad. **17**: 317. 1881–2.

Tall, somewhat pubescent with silky hairs, or smoothish: root-leaves biternate even in the petioles, leaflets deeply lobed and cut, green above, glaucous beneath; stem-leaves similar, petioled: flowers pale yellow, sepals lanceolate, broadly spreading, an inch or more, the spatulate petals a little shorter, about equalling the head of stamens; spur 4 inches long or more, always hanging, orifice narrow. Distinguished from *A. chrysantha* by longer spur with contracted orifice, by the narrow petals, and by the late season of flowering. Late July to October 1st. Ravines southwest Texas, into Mexico. The seed must be obtained from the wild plants, as those cultivated usually fail to produce seed; hence not much used. Garden & Forest 1: 31.

A. caerulea JAMES, Long Exped. Rocky Mts. 2: 15. 1826.
A. leptocera NUTT. in Journ. Acad. Phila. 7: 9. 1834.
A. macrantha HOOK. & ARN. Bot. Beech. Voy. 317, *t. 72.* 1841.

Stem 1½ feet high, finely pubescent above, bearing several flowers: lower stem-leaves large and biternate; basal leaves with long 3-branched petioles; leaflets 3-lobed on secondary stalks: flowers 2 inches across, whitish, but variously tinted with light blue and yellow; sepals often blue, oblong, obtuse, twice as long as the petal-limbs; spurs long, slender, knobbed at the end, rather straight but curving outward: head of stamens equalling the petals: follicles pubescent, 1 inch long; style ⅓ inch. April–July. Lower mountain regions, Montana to New Mexico. Introduced 1891. Bot. Mag. 4407. Garden 16: 198. Meehan's Mo. 6: 61. Vicks' 1: 33, *f. 4.* Bot. Mag. 5477 (as var. *ochroleuca*). Flor. des Serr. 5: 531.

Var. **albiflora** GRAY Syn. Fl. 1: 1: 44. 1895.

Flowers of the same size but sepals as well as petals almost white. Introduced as var. *alba* HORT. 1883.

Var. **alpina** A. NELSON Wyom. Exp. Sta. Bull. 28: 78. 1895–6.

Plant smaller than the type; upper leaflets entire; flowers smaller, yellow, spurs rather short.

Var. **calcarea** JONES Proc. Calif. Acad. Sci. II. 5: 619. 1895.

Plant glandular-pubescent: leaves and leaflets reduced, firm; flowers much smaller than the type; sepals blue-purple; petals reddish. Cannonville, Utah.

Var. **hybrida** HORT. Sepals some shade of blue or pink or mixed, and petals nearly white or yellow. The true form of this is probably *A. cærulea* X *A. chrysantha*. Revue Hort. 1896: 108. Am. Gard. 15: 315.

Var. **flore-pleno** HORT. Flowers longer and very showy; more or less doubled toward the center.

A. alpina LINN. Sp. Pl. 533. 1753.

A. montana STERNB. in Regensb. Denkschr. 2: 60. 1818.
A. Reuteriana REICHB. f. Nym. Consp. 18. 1878.
A. Sternbergii REICHB. Fl. Germ. Excurs. 749. About 1880.
A. alpina var. *superba* HORT.

Stem nearly 1 ft. high, finely pubescent in upper parts; 2–5 flowered: leaves biternate, petioled; partial-petioles of basal leaves 1–2 inches long with 3 nearly sessile leaflets, deeply lobed: expanded flower 1½–2 inches across, blue, rarely pale or white: sepals 1¼ inches long, half as broad, acute; petal-limb half as long as sepal, often white: spur slender, incurved, same length as the limb: head of stamens not protruding: follicles pubescent, 1 inch long, style much shorter. May-June. Switzerland. Bot. Cab. 7: 657. Garden 9: 17.

A. glandulosa FISCH. Hort. Gorenk. 2ed. 48. 1812.

Stem 1 to 1½ feet. high; glandular-pubescent in the upper half; 1–3 flowered: partial-petioles of root leaves 1–2 inches long, each with 3 distinct divisions; leaflet segments narrow and deep: stem-leaves few, bract-like: flowers large, nodding: sepals bright lilac-blue, ovate, acute, almost 1½ inches long and half as broad; petal-limb same color, but tipped and bordered with-creamy white, less than half the length of the sepals, very broad; spur very short, ¼ inch, stout, much incurved; stamens not protruding: follicles 1 inch long, 6–10 in number, densely hairy, with short falcate style. Allied to *A. alpina*, but with shorter spurs, larger flowers, plant taller, greater number of follicles. May–June. Altai Mts. of Siberia. Botanist 5: 219. Floral World 1871: 354. Garden 15: 174. Gartenflora 289, *f. l.*

Var. **jucunda** FISCH. & LALL. Ind. Sem. Petrop. 2. 1840. Flowers rather smaller than in the type; petal-limb white, more truncate at the tip; stamens as long as the limb. A variety with some tendency to double. Bot. Reg. 33: 19. Flor. des Serr. 5: 535.

A. Stuarti HORT. A recorded hybrid of *A. glandulosa* and *A. vulgaris* var. *Olympica*. Flowers very much resemble the latter parent in form of sepals and petals, and the former in shape of spurs and in coloration. May–June. Introduced 1891. Garden 34: 670.

XXI. A SYNONYMIC CONSPECTUS OF THE NATIVE AND GARDEN ACONITUMS OF NORTH AMERICA.

K. C. Davis.

This genus of hardy, ornamental, perennial herbs is much used in borders, and such places, and is commonly called Monkshood. Many species are planted in European gardens; nine only have been thus used in America. The number of species varies from 18 to 80, according to treatment by different authors. They are native in mountainous regions of Europe, temperate Asia, and 7 are found in North America.

Roots tuberous, turnip-shaped, or thick-fibrous: stem tall or long, erect, ascending, or trailing: leaves palmately divided or cleft and cut-lobed: flowers large, irregular, showy; sepals 5, the large upper sepal in shape of a hood or helmet; petals 2–5, small; stamens numerous; carpels 3–5, sessile, many-ovuled, forming follicles when ripened.

The following species do well in any garden soil, but rich soil is preferred. They thrive in open sun, but flowers last longer in shaded places. Aconites should never be planted in, or too near the kitchen garden, or the children's garden, as the roots and some of the flowers contain a deadly poison. Propagated easily by root division.

Besides the Prodromus treatment by A. DeCandolle, in 1824, the only other monographs of the whole genus are by H. G. L. Reichenbach, "Uebersicht der Gattung Aconitum," Leipsic, 1819; "Monograph Generis Aconiti," Leipsic, 1820, folio, 2 vols., and "Illustratio Spec. Aconiti," Leipsic, 1823–7, folio. Reichenbach considered the number of species to be about 80, but many of his names should be treated as synonyms, as they were given to forms varying only slightly from the type.

KEY TO SPECIES OF ACONITUM.

- A. Roots tuberous or napiform.
  - B. Leaves deeply cut, but not to the base.
    - C. Sepals mostly some shade of blue.
      - D. Axils of leaves without bulblets.
        - E. Beak of helmet prominent or reflexed.
          - F. End of beak reflexed........... *Cammarum.*
          - FF. End of beak not reflexed, but prominent.
            - G. Stem stout.................. *paniculatum.*
            - GG. Stem lax.............. *Kamtschaticum.*
        - EE. Beak of helmet either abruptly pointed or turned inward—not reflexed.
          - F. Stem stout, erect.................. *Japonicum.*
          - FF. Stem slender, sometimes showing a climbing tendency........................ *uncinatum.*
      - DD. Axils of leaves with bulblets............ *bulbiferum.*
    - CC. Sepals mostly white or yellow bordered with blue.
      - D. Stem robust............................... *heterophyllum.*
      - DD. Stem slender.............................. *Lycoctonum.*
  - BB. Leaves divided to the base.
    - C. Helmet higher than wide........................ *variegatum.*
    - CC. Helmet, or hood, broad and low.
      - D. Follicles rarely varying from four........... *Napellus.*
      - DD. Follicles three to five................ *delphinifolium.*
- AA. Roots fascicled and elongated, or fibrous.
  - B. Stems erect.
    - C. Flowers yellowish..................................... *Anthora.*
    - CC. Flowers blue to whitish........................... *autumnale.*
  - BB. Stems trailing............... .... *reclinatum.*

A. cammarum LINN. Sp. Pl. 2 ed. 751. 1762.

A. neomontanum WILLD. Sp. Pl. 2: 1236. 1799.

A. bicolor SCHULT. Obs. Bot. 101. 1809.

A. eriostemum DC. Syst. 1: 377. 1818.

A. intermedium DC. l. c. 374.

A. speciosum OTTO, ex DC. Prod. 1: 60. 1824.

A. cernuum BAUMG. ex. Schur. Enum. Pl. Transs. 32. 1866.

REICHENBACH has given the names: *austriacum* TRATT., *Breiterianum*, *decorum*, *exaltatum*, *hamatum*, *hortense* HOPPE., *Ottonianum*, *palmatifidum*, *Sprengelii* RUA, *Storkianum*, *versicolor*.

Stem 3–4 feet high; leaves with short bluntish lobes; flowers purple or blue: panicles or loose spikes few flowered; helmet hemispherical, closed: beak reflexed. July–Sept. Hungary. Introduced 1889. *A. Storkianum* RCHB. Uebers 49, is a form of this with dwarf habit and fewer flowers; roots somewhat fibrous. Bot. Cab. 1991.

A. paniculatum LAM. Fl. Fr. 3: 646. 1778.
A. cernuum WULF. ex Koelle, Spicil. 17. 1786.
A. humile SALISB. Prod. 375. 1796.
A. Wilematianum DELARB. Fl. Anv. 2 ed. 499. 1800.
A. hebegynum DC. Syst. 1: 376. 1818.
A. camarum SCHLEICH. Cat. 5. 1821.
A. neomontanum BAUMG. Enum. Transs. 2: 100. 1816–46.
Forms were named by REICHENBACH: *acuminatum*, *plexicaule* HOPPE & HORN, *galectonum*, *gibbiferum*, *molle*, *parviflorum*, *taxicum*, *reflexum*.

Stem erect, slender, 2–3 feet high; leaves glabrous, rather thin, deeply 3–7 cleft, the divisions obovate, cuneate, incised and dentate; inflorescence pubescent, panicled; flowers blue, few, half as broad as high; helmet with a gibbous arch; beak very prominent and descending, ¼ inch long; open; follicles usually 4, erect, ¼ inch long. Summer. Central Europe. Well figured in Bot. Cab. 810.

A. Noveboracense Gray ex Coville in Bull. Torr. Club, 13: 190. 1886, of South-eastern New York, differs very little, if any, from this.

A. Kamtschaticum PALL. ex Rchb. Uebers. 39. 1819.
A. Napellus THUNB. Fl. Jap. 251. 1784, not Linn.
A. maximum PALL. ex. DC. Syst. 1: 380. 1818 (name only).
A. Fischeri RCHB. Monog. *t. 22.* 1820.
A. Labanskyi RCHB. l. c. *t. 40.*
A. abbreviatum LANGSD. ex DC. Prod. 1: 61. 1824.
A. nasutum HOOK. Fl. Bor. Am. 1: 26. 1833.
A. sinense SIEB. & ZUCC. 1835, not *Chinensis* Siebold.
A. Columbianum NUTT. in Torr. & Gray, Fl. 1: 34. 1838.
A. autumnale LIND. in Journ. Hort. Soc. 2: 77. 1847.
A. arcuatum MAXIM. Fl. Amur. 27. 1859.
A. Californicum Hort.

Roots napiform; stem lax, 2–4 ft. high, pubescent in upper parts: leaves parted or deeply cleft, divisions broadly ovate or cuneate and incised and dentate: flowers pale blue; helmet higher than broad, being ½–¾ in. long; beak often elongated; lower petals small, oblong: follicles erect, oblong, reticulate. Autumn. Of wide geographic range, being found in many parts of Asia, Europe and in the U. S. west of the Rockies. Introduced 1889. Bot. Mag. 7130.

A. Japonicum DECNE. in Rev. Hort. 473. 1851.

Stem erect, 3–4 ft. high, smooth; leaves dark green, shining, petioled, lobes 2–3 times cut, parts blunt and deeply toothed; flowers large, deep blue or violet tinged with red; loose panicles with ascending branches: helmet conical, beak abruptly pointed: follicles 5. July–Sept. Japan. Introduced 1889. Rev. Hort. l. c.

Var. **coeruleum** Hort. Flowers very abundant; panicles shortened.

A. uncinatum LINN. Sp. Pl. 2 ed. 750. 1762.
A. Japonicum THUNB. Fl. Jap. 232. 1784.
A. volubile MUHL. Cat. 52. 1813.
A. scandens MUHL. ex Rchb. Uebers. 38. 1819.
A. variegatum HOOK. f. & THOMS. Fl. Ind. 56. 1858.

Stem slender, 3–5 ft. high; inclined to climb; glabrous below the inflorescence: leaves thick, deeply cut into 3–5 cut-toothed lobes: flowers loosely panicled but crowded at the apex; blue, pubescent, 1 inch broad; helmet erect, nearly as broad as long, obtusely conic, beak or point of helmet turned inward: follicles 3, ½ in. long. June–Sept. Low grounds of Penn., South and West, Japan. Much planted now. Meehan's Mo. 4: 81. Bot. Mag. 1119.

A. bulbiferum HOWELL, Fl. N. W. Am. 1: 25. 1897.

Stems slender, weak and viney, 2–4 ft. long; smooth below, tomentose above: leaves rather small, on short petioles, or the upper sessile, bearing bulblets in their axils, all laciniately cut into acute lobes: sepals pale blue; hood 6–8 lines long. Fruit not seen. In marshes on the eastern slope of the Cascade Mts. near Mt. Hood. Flowering in Sept. Described from the original.(†)

A. heterophyllum WALL. Cat. 4722. 1828. Bot. Mag. 6092. 1874.
A. cordatum ROYLE. Illustr. 56. 1839. not Rafin.

Stem robust, 3 ft. high: lower leaves petioled, upper ones sessile; all dark, large, cordate, coarsely dentate: sepals yellow with violet or blue margins; hood arched, beak rather blunt: follicles 5, erect pubescent. Widely distributed. Himalaya region. Not yet introduced to the American trade, but has recently been used in European gardens because of its striking flowers and leaves. It is used in India as a tonic medicine.

A. Lycoctonum LINN. Sp. Pl. 532. 1753.

A. Pyrenaicum LINN. l. c. 532.
A. altissimum Mill. Gard. Dict. 8 ed. no. 2. 1768.
A. Napellus S. G. GMEL. It **1**: 8. 1768 (?).
A. septentrionale KOELLE. Spicil. 22. 1786.
A. taxicarium SALISB. Prod. 375. 1796.
A. intermedeum Host. Fl. Aust. **2**: 69. 1797.
A. Jacquinianum HOST. l. c. 68.
A. pauciflorum HOST. l. c. 70.
A. ochroleucum WILLD. Sp. Pl. **2**: 1233. 1799.
A. barbatum PATR. ex Pers. Syn. **2**: 83. 1807.
A. galeriflorum STOKES, Bot. Mag. Med. **3**: 216. 1812.
A. Neapolitanum TENORE, Fl. Nap. **1**: 327. 1815.
A. hispidum DC. Syst. **1**: 367. 1818.
A. squarrosum LINN. ex DC. l. c. 368.
A. ochranthum C. A. MEY. in Ledeb. Fl. Alt. **2**: 285. 1830.
A. delphinifolium HORT. ex Steud. Nom. 2 ed. **1**: 18. 1840.
A. ochroleucum HORT. ex Steud. l. c. 19.
A. rubicundum FISCH. ex Steud. l. c. 20.
A. triste FISCH. ex Steud. l. c. 20.
A. excelsum TURCZ. Cat. Baikal. 70. 1842.
A. Hosteanum SCHUR. in Verh. Seibenb. Ver. Naturw. **2**: 177. 1851.
A. Transilvanicum LERCH. ex Schur. in same, **10**: 165. 1859.
Lycoctonum sylvaticum FOURR. in Ann. Soc. Linn. Lyon, n. s. **16**: 326. 1868.
A. umbracticolum SCHUR. in Verh. Naturf. Ver. Bruenn. **15**: 2. 1877.

Names of this accredited to REICHENBACH are: *ægophonum*, *alienum*, *arctophonum*, *australe*, *loreale* SER., *cynoctonum*, *dissectum* TAUSCH., *Gmelini*, *lagoctonum*, *Lamarckii*, *luparia*, *lupicida*, *meloctonum*, *moldavicum*

HACQ., *monanense* SCHMIDT., *myoctonum*, *pallidum*, *perniciosum*, *Phthora*, *ranunculifolium*, *rectum* BERNH., *strictissimum*, *strictum* WILLD., *thelyphonum*, *theriophonum*, *tragoctonum*, *vulparia*, *zooctonum*.

Stem slender, simple, 3–6 feet high; leaves deeply cut into 5–9 lobes: long petioles and under ribs pubescent: flowers yellow or whitish in racemes; helmet a pinched elongated cone; middle sepals usually bearded: follicles usually 3. June–Sept. Europe; Siberia. Bot. Mag. 2570. Gard. Mag. 34: 124.

A. variegatum LINN. Sp. Pl. 532. 1753.
A. alpinum MILL. Gard. Dict. 8 ed. No. 7. 1768.
A. cammarum JACQ. Fl. Aust. 5. *t. 224*. 1775.
A. luridum SALISB. Prod. 375. 1796.
A. volubile MOENCH. Meth. Suppl. 110. 1802.
A. rostratum BERNH. Ind. Sem. Hort. Erf. 1815.
A. glabrum DC. Syst. 1: 379. 1818.
A. leucanthemum WENDER. in Linnaea 5: 53. 1830.
A. nasutum FISCH. ex. G. Don. Gen. Syst. 1: 61. 1831.
A. intermedium GAUD. ex Steud. Nom. 2 ed. 1: 18. 1640.
A. Japonicum Hort. ex STEUD. l. c. 18.
A. laciniosum SCHLEICH. ex Steud. l. c. 18.
A. laevigatum SCHLEICH. ex Steud. l. c. 18.
A. uncinatum Hort. ex STEUD. l. c. 20.
A. altigaleatum HAYNE, Arzn. Gew. 12, *t. 16*. 1845.
A. Burnhardianum WALLR. Sched. Crit. 1: 250, *t. 2*. 1848.

REICHENBACH'S names for forms of this are: *bulbiferum*, *flexuosum* PRESL., *gracile*, *hamatum*, *illinitum*, *italicum* TRATT., *lasiocarpum*, *macranthum*, *mixtum*, *rhynchanthum*.

Erect, 1–6 ft. high: leaves variously divided into usually broad lobes and cut divisions: lower petioles long, others short or none: flowers in a loose panicle or raceme; blue varying to whitish, smoothish; helmet higher than wide, top curved forward; beak pointed horizontal or ascending. July. Europe.

Var. **album** n. var.
A. album AIT. Hort. Kew. 2: 246. 1789.

A pure white form of above type, with roots rather fibrous.

A. Napellus LINN. Sp. Pl. 532. 1753.
A. pyramidale MILL. Gard. Dict. 8 ed. no. 6. 1768.

A. tauricum WULF. in Jacq. Coll. **2**: 112. 1788.
A. neubergense DC. Syst. **1**: 373. 1818.
A. strictum BERNH. ex DC. l. c. 373.
A. laxiflorum SCHL. Cat. 5. 1821.
Napellus vulgaris FOURR. in Ann. Soc. Linn. Lyon, n. s. **16**: 326. 1868.

REICHENBACH has given twenty-four names to forms of this: *acutum*, *ambiguum*, *amœnum*, *Bernhardianum*, *Braunii*, *callibotryon*, *clusianum*, *commutatum*, *firmum*, *formosum*, *Funkianum*, *hians*, *Hoppeanum*, *Koehleri*, *lœtum*, *laxiflorum* SCHL., *laxum*, *Mielichhoferi*, *napelloides* SW., *oligocarpum*, *rigidum*, *tenuifolium*, *venustum*, *virgatum*.

The best known, as well as the most poisonous species. Stem erect, 3–4 ft. high: leaves divided to the base and cleft 2–3 times into linear lobes: flowers blue in a raceme: peduncles erect, pubescent: helmet broad and low, gaping, smoothish: follicles 4, rarely 3. June–July. Europe, and naturalized here. Gartenflora, 35: 227 (named *A. dissectum* Don.). Regne Végétal, Med. *Pl. 2*. There are very many varieties, differing in shade of flowers, often mottled or lined with white. Var. *album* is nearly white. Var. *bicolor* and Var. *versicolor* are much used in gardens for the large blue-and-white flowers. Bot. Cab. 8: 794 (*versicolor*).

A. delphinifolium DC. Syst. **1**: 380. 1818.
A. Napellus var. *delphinifolium* SERINGE, Mus. Helv. **1**: 159. 1823.

REICHENBACH used for forms of this: *Chamissonianum*, *paradoxum*, *semigaleatum*.

Stem erect, 1–3 feet high, pubescent: leaves deeply parted, and cleft into narrow lobes: flowers blue, large; hood low, beak short; lateral sepals as long and twice as broad as the lower: follicles oblong. British Columbia and Alaska through islands of Behring Strait to Asia.

Var. **ramosum** n. var.
A. ramosum A. NELS. Bull. Torr. Club **26**: 8. 1899.

Much like the type: leaves larger with fewer and longer segments: follicles less pubescent. Professor Nelson considers the pubescence different. Only once found: Limestone Range, Black Hills, Weston Co., Wyom. Co-type at Columbia. (†)

A. Anthora LINN. Sp. Pl. 532. 1753.
A. Pyrenaicum PALL. Reise. 2: 316. 1776.
A. ochroleucum SALISB. Prod. 375. 1796.
A. Anthorideum DC. Syst. **1**: 366. 1818.
A. Anthorum ST. LAG. in Ann. Soc. Bot. Lyon, **7**: 119. 1880.

REICHENBACH used these names: *Candollei*, *eulophum*, *Jacquini*, *nemerosum*, BIEB., *Pallasii*, *tuberosum* PATR.

Stem erect, 1–2 feet high: leaves parted, usually at the base, parts deeply cut and lobed; more or less hispid beneath, smoothish above; petioles long: flowers in lateral and terminal racemes, pale yellow, often large; inflorescence generally pubescent; spur refracted or hooked; helmet arched but cylindrical at base: follicles 5. June–July. Southern Europe. There are several garden varieties differing in pubescence, size of flower, shape of galea, and width of leaf segments. Bot. Mag. 2654.

A. autumnale REICHB. Monog. *t. 17, f. 2.* 1820.

Stem erect, 3–5 feet high: leaves pedately five lobed: flowers in simple spike becoming a panicle; blue, lilac, or whitish; helmet closed. Sept.–Nov. North China. Introduced about 1870.

A. reclinatum GRAY Am. Journn. Sci. 42: 34. 1842.

Stem always trailing, 2–5 feet long, nearly glabrous; leaves thin, deeply 3–7 cleft, toothed and cut, lower ones petioled, large, upper ones sessile; flowers white or dull cream-color, pubescent, in loose raceme or simple panicle: helmet twice as high as wide, conic; beak very short; follicles 3, nearly ½ inch long. Summer. Wooded mountain regions of Va. to Ga. (†).

NOTE: The mark (†) indicates that the native species or variety has not yet been introduced to the American trade. Citations at the end of a description are mostly to colored plates.

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